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SEDIMENT-RELATED LITERATURE FOR THE WESTERN AND NORTHERN REGION: ANNOTATED BIBLIOGRAPHY

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Canada

Western and Northern Region

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SEDIMENT-RELATED LITERATURE FOR THE WESTERN AND NORTHERN REGION: ANNOTATED BIBLIOGRAPHY

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ABSTRACT

This report consists of a compilation of reference material pertaining to sediment in the Western and Northern Region of Inland Waters Directorate, Environment Canada.

It is divided into two sections: 1) references and abstracts and 2) a subject cross-reference index. Subjects cover a wide range of interests such as quality aspects of sediments, erosional processes, sedimentation in reservoirs, lakes and rivers and sediment transport in rivers.

RESUME

Ce rapport est un catalogue de références concernant les sédiments dans la région de l'Ouest et du Nord, Direction des eaux intérieures, Environnement Canada.

Il est divisé en deux sections: 1) références et résumés et 2) un index de renvois par sujet. Les sujets englobent une large gamme d'intérêts tels la qualité des sédiments, les processus d'érosion, la sédimentation dans les réservoirs, les lacs et les rivières et le transport de sédiments dans les rivières.

INTRODUCTION

This report presents a compilation of reference material on subjects related to the erosion, transportation and deposition of sediments in the Western and Northern Region of Inland Waters Directorate, Environment Canada (Alberta, Saskatchewan, Manitoba and Northwest Territories).

The 314 references included in this bibliography cover a wide range of subject matter such as suspended sediment transport in rivers, reservoir sedimentation, river morphology and erosion studies.

The report is organized as follows:

1. A sequentially numbered alphabetical listing of references by author. Information on author, title and source is provided. In addition, an abstract or summary is given, which is either copied directly from the reference or compiled by the authors of this report.

2. A cross-reference index by subject matter. On page 180 a cross-reference list is provided. References identified by number are grouped under titles such as data sources, dissolved material, river morphology, networks, river regime and hydraulic processes, sediment transport, sediment yield and water quality aspects.

While the authors believe that most of the major references have been included it is realized that this compilation is incomplete. The authors would appreciate receiving additional references.

REFERENCES AND ABSTRACTS

1. ABRAHAMS, A.D. and KELLERHALS, R.
1973: Correlation Between Water Discharge and Concentrations of Suspended Solids for Four Large Prairie Rivers; Proceedings of the 9th Canadian Hydrology Symposium on Fluvial Processes and Sedimentation, University of Alberta, Edmonton, May 8-9, p. 96-113.

ABSTRACT:

Five to nine years of suspended sediment records are now available for several large prairie rivers. These data are used here to investigate to what degree the discharge hydrograph, Q(t), can serve as a predictor for concentration of suspended solids, C(t), and for suspended load, L(t). The analysis is based on successive three-year periods to permit testing the derived equations for consistency.

Multiple linear regression of mean daily values of log C on sixteen parameters of the corresponding discharge hydrograph shows that a variety of parameters make statistically significant contributions to the regression but most of the regression coefficients are unstable, due mainly to serial correlation in the data. For three of the four rivers considered here, only the relation between log C and the log-transferred discharge, log Q, is sufficiently stable to justify its adoption as a rating curve. On one river, a second variable appears to make a stable and physically plausible contribution to the regression.

2. ABRAHAMS, A.D. and McPHERSON, H.J.
1972: Sediment Yields in Southern Alberta; Progress Report to Highways Division, Research Council of Alberta, 13 p. + Appendices.

ABSTRACT:

In this paper, the authors propose a model to predict sediment yields from ungauged drainage basins. Long-term average sediment yield from each drainage basin will be determined by means of the flow duration and the sediment-rating curve methods. Multivariate analysis will be used to identify the principal factors (climatic, geomorphic and geologic) controlling sediment yield.

3. ALBERTA DEPARTMENT OF THE ENVIRONMENT
1977: Buffalo Bay Sedimentation Study; Interim Report, Environmental Engineering Support Services, Technical Services Division, 95 p.

ABSTRACT:

A small number of suspended sediment measurements and sediment size analyses indicate that the amount of sand and silt entering Buffalo Bay cannot be reduced by controlling erosion of the East and West Prairie Rivers. The channel erosion source is predominantly fine sand and coarse silt which is deposited upstream of Buffalo Bay. 85% of the annual suspended sediment load is deposited on channel beds and on the adjacent flood plain by water flowing through breaks in levees and dykes (avulsions). Several more years of measurement are necessary to make this conclusion definite.

4. ALBERTA ENVIRONMENT
1981: Lesser Slave Lake Regulation, Environmental Impact Assessment, Volume III, Land Use Impact Studies, Report by Alberta Environment, Planning Division.

ABSTRACT:

This volume on land use impact studies consists of three appendices. Appendix One reports on possible hydrologic effects of the Lesser Slave Weir and Canal. Water levels in the lake are described and the rate of drop of spring flood levels is recorded and analyzed. The flushing rate of the lake is described as well as the probable shoreline sediment draft. The probable increase in gradient of inflowing streams due to lowering of the main lake level is discussed and probable consequences such as increased river degradation, movement of deltas and sediment load are noted. A description is given of the Buffalo Bay area following completion of the project. Tributary characteristics and potential impacts are listed. Appendix Two describes an investigation into the groundwater conditions at the east end of Lesser Slave Lake and predicts the potential effect of the canal operation on local groundwater and lake levels. Appendix Three presents land use studies. It inventories existing conditions, discusses impacts, and suggests measures for monitoring and minimizing negative impacts. The subject areas considered are land use, agricultural and recreational capability, and vegetation. Procedures for reclamation of areas disturbed during canal and weir construction are outlined.

5. ALBERTA ENVIRONMENT
1983: Pesticides and PCB's in the North Saskatchewan River and Red Deer River; Internal Report, Alberta Environment Centre, Vegreville, Alberta, 24 p.

ABSTRACT:

This study describes the concentrations of pesticides and PCBs in fish collected between 1980 and 1982 from the North Saskatchewan River and the Red Deer River. Approximately 500 fish, mainly pike, walleye, sauger, goldeye and suckers, were collected. Determinations were made on both muscle and intestinal fat samples for a total of 45 compounds, including most pesticides commonly concentrations in sediments from the North Saskatchewan River were also measured. Based on these collections, it is concluded that the concentrations of all compounds in fish were generally low and presented no immediate threat to human consumers. PCB residues in muscle tissue of fish from the North Saskatchewan River ranged from less than 0.1 to 1.66 mg/kg depending on species, compared to less than 0.5-104.0 mg/kg for intestinal for samples. Residues in fish collected from the Edmonton area were not significantly higher than those found in other parts of the river. PCB concentrations in sediments were generally below 0.01 mg/kg from Edmonton to the Saskatchewan border. Maximum PCB levels in the muscle tissue of fish from the Red Deer River ranged from less than 0.01 to 0.72

mg/kg, depending on species, compared to less than 0.01-15.9 mg/kg for intestinal fat samples. Methoxychlor was frequently found in goldeye from the North Saskatchewan River but was not recorded in any Red Deer River sample. Its presence in goldeye, a highly migratory species, was probably a result of biting fly control programs in the Saskatchewan portion of the river. Since PCBs, their metabolites and methoxychlor are known mutagens and potential carcinogens, the long term fate and partitioning of these compounds should be determined.

6. ALLAN, R.J.
1979: Heavy Metals in Bottom Sediments of Great Slave Lake (Canada): A reconnaissance; Environmental Geology, Vol. 3, No. 1, p. 49-58.

ABSTRACT:

Near the shores of Great Slave Lake, natural sources of heavy metals include gold and base metal deposits, mineralized greenstone belts and sedimentary bedrock, and uraniferous granites. Potential anthropogenic sources of heavy metals (As, Zn, Pb) include large gold and base metal extraction- processing facilities on the shores of the lake. Six sediment cores were collected on a traverse of the lake. Heavy metal concentrations and distributions are related to the regional bedrock geochemistry in the drainage basin. Higher uranium concentrations in the northernmost core are attributed to extensive uraniferous areas north of the lake. More subtle variations of concentration are related to sedimentologic characteristics and processes in the lake. The west basin is a natural sink for most of the heavy metals determined. Two centrally located west basin cores and mean zinc concentrations of 145 ppm, whereas cores closer to the north and south shores had mean concentrations of 80-100 ppm. Mn, Ni, and Pb were enriched in some of the cores from the area of Shallower water near the Mackenzie River outlet, rather than in the central west basin. The enrichment is related to Mn^-, Ni^-, and Pb^- rich amorphous coatings on quartz grains. Elevated zinc or lead levels from anthropogenic activities were not detected but elevated levels are suspected for arsenic. In the two cores from the center of the west basin, surface sediment contains up to 12 ppm arsenic, not high in comparison with noncontaminated freshwater lakes elsewhere in Canada but considerably elevated relative to concentrations of 1 ppm found deeper in the same cores.

7. ALLAN, R.J.
1979: Sediment-Related Fluvial Transmission of Contaminants: Some Advances by 1979; Scientific Series No. 107, Environment Canada, Inland Waters Directorate, Western and Northern Region, 24 p.

ABSTRACT:

Suspended sediment can be a major transport mechanism for nutrients and contaminants in drainage systems. Bottom sediment pollution has been extensively studied, but until recently suspended sediment has seldom been chemically analyzed. Sufficient suspended sediment

could not be collected for detailed nutrient and contaminant analysis until the advent of land-based continuous flow centrifuges. This report describes the evolution of this area of investigation and the stage of development reached in Canada as of 1979. Problems of sampling and analytical requirements are discussed. Examples are included of the types of results being obtained by the main Canadian investigators. Relationships between suspended and bottom sediment chemistry are described. Interaction between those involved in sediment surveys for engineering purposes, water quality monitoring, and research into drainage system contaminant transmission is advocated. Such interaction could rapidly extend existing knowledge in this area, critical to pollution control and environmental basin management.

8. ALLAN, R.J. and BRUNSKILL, G.J.
1976: Relative Atomic Variation (RAV) of Elements in Lake Sediments: Lake Winnipeg and Other Canadian Lakes; Proceedings of the Symposium on the Interactions Between Sediments and Fresh Water, Amsterdam, September 6-10, 1976, p. 108-120.

ABSTRACT:

From 1968 to 1971 and again in 1975, lake sediment samples were obtained for geochemical study from sites throughout Lake Winnipeg, Manitoba. The objectives were twofold. We wished to determine the influence of agricultural, industrial and urban-domestic development of the 414,000 square mile drainage basin of the lake on the element concentrations in bottom sediments. A second objective was to investigate the validity of making qualitative assessments of cultural contamination on element concentration differences alone. Although concentrations alone have proved a valid means of identifying contamination at sites of extreme additions, various parameters including sedimentation rate, sediment type, particle size, and analytical methods make comparisons between sites difficult. It is proposed here that a dimensionless index based on ratios for various element combinations is a useful tool for detection of geochemical imbalances in lake sediments. This dimensionless index is called the relative atomic variation (RAV) and is the slope of the significant linear regression line for a particular element pair. Similarity in RAV implies similarity of eventual homogeneity in a large number of processes in the geochemical cycle including weathering, transport, deposition and diagenesis. RAV for various element pairs was calculated for sediments from the two basins of Lake Winnipeg and for sediments from lakes in geographically and geologically dissimilar areas of Canada. Surprisingly there was a great deal of correspondence in many of the values. Most exceptions could be related to cultural activities. Although the approach advocated has been applied here exclusively to lake sediments, it is thought to have greater significance to the study of river sediment geochemistry of contamination, because of the relative difficulty in obtaining meaningful cores of river sediments.

9. ALLAN, R.J., CAMERON, E.M. and DURHAM, C.C.
1973: Reconnaissance Geochemistry Using Lake Sediments of a 36,000 Square Mile Area of the Northwestern Canadian Shield (Bear-Slave Operation, 1982); Geological Survey of Canada, paper 72-50, 70 p.

ABSTRACT:

The Bear-Slave operation is a regional helicopter-supported, geochemical survey of some 36,000 square miles of the central parts of the Bear and Slave structural provinces of the Canadian Shield. The regional survey area extends from 64 degrees 30 minutes north to 66 degrees 00 minutes north and from 106 degrees 00 minutes west to 118 degrees 00 minutes west, covering nine 1:250,000 scale map-sheets. Nearshore, inorganic, silty, lake sediment and surface lake water were the sample media collected at a site density of one per ten square miles. Sampling was carried out from June 25th to August 2nd. Three Bell G4A helicopters were used as transport for lake sampling. A DHC-3 otter aircraft was used to set out gas caches. Helicopter traverses were crudely radial in pattern. All helicopters operated from the same base camp so that three consecutive camps were established. Average flying time per sample site was less than 10 minutes. Approximately 1,500 square miles was sampled each day. Water samples were acidified and sediment samples dried in the field. Sediment samples were sieved to minus 250 mesh (63 micro) and sample preparation was completed in Ottawa by the end of September. Analysis by D.C. are emission spectrometric, atomic adsorption spectrophotometric, fluorimetric, and colorimetric methods are being undertaken in the laboratories of the geological survey, geochemistry section. The sediment samples are being analyzed for Cu, Ni, Pb, Zn, Ag, Co, Mn, U, Hg, Mo, Ti, Ba, Cr, Be, V, Zn, Zr, Y, La, Li, Mg, Fe, K, Ca, Sr, Sb and As. Water samples are being analyzed for Cu, Zn and Hg. The data are being published as 1:250,000 scale maps on which the element concentration at each sample site and geochemical contours drawn by computer will be superimposed on a base showing geology, lakes and drainage, and sample site locations. The most significant elements will be published at this scale. The remaining data will be published as computer data listings and small scale contour maps along with a map showing sample locations and numbers. Preliminary results show that there are significant anomalies for several elements within the survey area. Follow-up procedures for such anomalies are outlined. Costs of the operation are itemized.

10. ALLAN, R.J. and JACKSON, T.
1978: Heavy Metals in Bottom Sediments of the Mainstem Athabasca River System in the AOSERP Study Area; Alberta Oil Sands Environmental Research Program, Edmonton, Alberta, 72 p.

ABSTRACT:

Dredged sediments and sediment cores were collected from sites along the Athabasca River system from between Fort McMurray and the confluence of rivière des Rochers with the Slave River. A selected sampled suite representing all of the drainage units and textural variations was analysed by several total and partial element

extraction techniques. None of the metal concentrations detected were unusual. The results indicate that total concentrations are low when compared to data for natural and for polluted sediments elsewhere. Concentration variations are functions of natural fluvial, geochemical processes and are strongly affected by sedimentological parameters including sediment texture, Fe and Mn mineral coatings, organic and carbonate contents. There was a general progression to higher concentrations of heavy metals downstream from the Athabasca River to its delta to Lake Athabasca. The highest heavy metal concentrations were in the fine textured sediments from Lake Athabasca. Vanadium and nickel were strongly correlated with each other and with organic carbon content. V and Ni appear to be present in the bottom sediment in an organic form, unextractable by benzene/methanol, sodium hydroxide, or dilute hydrochloric acid.

11. ALLAN, R.J. and WILLIAMS, J.D.H.
    1978: Trophic Status Related to Sediment Chemistry of Canadian Prairie Lakes; Journal of Environmental Quality, Vol. 7, No. 1, p. 99-106.

    ABSTRACT:

Concentrations of different sediment phosphorus forms vary in the prairie lakes studied. Extremely high surface sediment available P concentrations in the fishing lakes of southern Saskatchewan were related to P loading from municipal and other cultural sources. Mean available P concentrations in surface sediments from the fishing lakes are higher than those found in other prairie lakes and in most other canadian lakes. Sediment cores show that presettlement concentrations of available P in the fishing lakes are higher than occur today in surface sediments from culturally eutrophied lakes, such as Lake Erie, elsewhere in Canada. Free iron is concentrated in the surface 10 to 15 cm of sediment cores from the fishing lakes and Lake Erie. Such a distribution, when coupled to low free Fe / available P ratios, is considered to reflect conditions favorable for P regeneration when anoxic conditions develop under winter ice cover. For the winter of 1976-1977, a mean sediment phosphorus release rate of 8.6 mg sq.m. per day was calculated for the fishing lakes.

12. ANDERSON, J.C.
    1980: Hydrologic Studies in the Mackenzie Delta Region, N.W.T., 1979; 1980 Report for the Northern Roads Environmental Working Group, Department of Indian Affairs and Northern Development, 39 p. + Appendix.

    ABSTRACT:

Hydrologic investigations continued during the 1979 open water season at several watersheds in the taiga and tundra zones of the eastern Mackenzie Delta region, N.W.T. Data were gathered on snowpack water equivalent, river channel and culvert icings, precipitation, air temperature, river discharge, suspended sediment and stream water temperature. Culvert icings to the south of Inuvik were of intermediate magnitude, while to the north, a major

river icing recurred on Hans Creek, upstream of the proposed highway crossing. In both taiga and tundra, late winter snowpack water equivalents were low. Nevertheless, snowmelt produced the largest flood event of the season but peak flows were well below the 50-year design curve values. Relatively low suspended sediment concentrations were measured during the spring flood. A reconnaissance of stream crossings along the Mackenzie and Dempster Highways from Inuvik to the N.W.T.-Yukon border in early May revealed very few problem areas from a hydrologic viewpoint.

13. ANDRES, D.
1979: Paddle River Damsite 7B, Sedimentation Study; Internal Report, Alberta Environment, Engineering Support Service, Technical Service, 23 p.

ABSTRACT:

The proposed Paddle River dam located at Site 7B will act as a sump for 258 square miles of sediment producing area. Based on suspended sediment measurements and calculated bed material transport rates the dam will interrupt approximately 75,000 tons of sediment annually. Approximately 90% of this material can be classified as wash load and therefore is fine silt and clay. The proposed reservoir has a maximum capacity of 40,000 acre-feet and a permanent pool of 18,000 acre-feet. Depending upon how the dam is operated about 85 to 100% of all the material entering the reservoir will be deposited. Because this sediment is essentially silt and clay (having a low specific weight), 53 acre-feet of storage will be lost annually. Based on a design life of 50 years, it is recommended that 2,650 acre-feet be allotted to sediment storage.

14. ASHMORE, P.E.
1979: Laboratory Modelling of Braided Streams; Unpublished M.Sc. Thesis, Department of Geography, University of Alberta, Edmonton, 201 p.

ABSTRACT:

Basic hydraulic modelling principles along with a knowledge of channel pattern thresholds allow the development of a model braided stream with flow characteristics and equivalent dimensions of a natural river. Using a constant discharge and flume slope and maintaining approximate equilibrium with an adjustable sediment feed the forms and processes of natural gravel braided rivers are reproduced.

Beginning from a straight trough braiding is initiated by development of a series of alternating bars and scour pools which produce bends of increasing amplitude leading finally to channel division. These mobile, lobate bars which advance downstream by accretion on a lee-side avalanche face, together with the scour pools with which they are necessarily closely associated, are the fundamental elements of the channel pattern. Channel migration and division is a response to bar formation and these adjustments leave portions of the originally lobate forms show varying degrees of preservation of the original depositional units. Such complexes display a bewildering array of forms arising either from systematic migration and accretion of units as in the case of some dial and point bar complexes, or in a less systematic fashion because of channel avulsion.

Channel division is normally by avulsion or by division on an active bar surface. This is caused by vertical accretion leading to the central portion of the downstream extremity of the lobe becoming inactive and eventually exposed.

The forms identified in the flume channel are similar to those seen in the Sunwapta River, Alberta (a gravel braided stream) as well as published illustrations of both braided and low sinuosity meandering streams.

Surface sorting of sediment shows several identifiable patterns. Notably bar lobes show a fining downstream on their surfaces and an accumulation of coarse material at the base of the avalanche faces. The pattern may relate to the vertical sorting on the avalanche face which builds downstream. Scour pools show no lag deposits at peak flow but as flow declines a coarse layer is the first to accumulate. Other local sorting patterns include the accumulation of very fine deposits where weak secondary currents are evident and the accumulation of coarse veneers on exposed bar heads. Sediment sorting patterns indicate that mechanisms other than a simple lag principle must be used to explain many elements of size sorting patterns.

Hydraulic geometry measurements of stable channels chosen at random gave exponents of 0.619, 0.261 and 0.120 for width, depth and velocity respectively. These compare well with published data from streams in non-cohesive material. Using d_{50} as the principle scaling factor the model channels and data from the Sunwapta River plotted in the same region of graphs of relative depth and relative width versus dimensionless discharge. This is encouraging in terms of the quality of the modelling and gives added credence to the descriptive information.

15. ASHMORE, P.E.
    1982: Laboratory Modelling of Gravel Braided Stream Morphology; Earth Surface Processes and Landforms, Vol. 7, p. 201-225.

ABSTRACT:

Hydraulic modelling principles, together with a knowledge of channel pattern thresholds, allow the development of a small scale model of a gravel braided stream with flow characteristics and equivalent dimensions of a natural river. The forms and processes of natural gravel braided rivers are reproduced by imposing a constant flume discharge and slope, and maintaining approximate equilibrium with an adjustable sediment feed.

Beginning from a straight trough, braiding is initiated by development of a series of alternating bars and scour pools which produce bends of increasing amplitude, leading finally to channel division. These lobate bars accrete downstream by deposition of bed material at their margins, often in the form of avalanche faces. Together with the scour pools with which they are necessarily closely associated, these bars are the fundamental elements of the channel pattern. Channel migration and division is a response to the development of bars, and these adjustments leave portions of the originally active bars in the form of exposed and eroded remnants. Complex flats built from these lobate forms show varying degress of preservation of the original depositional units, but the model allows observation of the systematic construction of some flats.

Sorting of sediment on active bars with avalanche faces shows a distinct fining downstream. This may be the result of the accretion of fining upwards avalanche faces along the bar margins rather than a 'winnowing out' of fine material.

The processes and forms observed in the model appear to be very similar to those occurring in natural gravel braided streams during peak flows.

16. ASHMORE, P.E.
1985: Process and Form in Gravel Braided Streams: Laboratory Modelling and Field Observations; Unpublished Ph.D. Thesis, Department of Geography, University of Alberta, Edmonton, 414 p.

ABSTRACT:

Aspects of sediment transport, channel morphology and sedimentary processes in gravel braided streams were examined using Froude number modelling to produce small-scale laboratory streams, augmented by field data from Sunwapta River, Alberta.

Ten laboratory runs, each of 60 hours duration, were carried out at seven different combinations of slope and discharge. Mean bedload transport rate is positively correlated with discharge and stream power index. When adjusted for the critical conditions of motion, dimensionless sediment transport rates in the model runs compared closely with measured rates in published studies of several field gravel rivers and laboratory streams, and with the empirical and theoretical relationships of Meyer-Peter and Müller (1948), Einstein (1950) and Parker (1978).

Absolute confluence scour depth is largely a function of total discharge and confluence angle. Scour depth relative to the depth of the confluent channels varies from about 2 to 7 in the laboratory and field data. This depth is primarily a function of confluence angle and secondarily of the proportion of the total discharge carried in each confluent channel. Field and laboratory data for these relationships are closely comparable. Scour holes do not become armoured during their formation; the flow in the scour hole has a slightly greater competence than that in the confluent channels. The confluences exert considerable influence on the location of aggradation and channel division immediately downstream of scour holes.

Braiding may be initiated from a straight channel by one of three mechanisms: cut-off of meanders developed from alternating bars, mid-channel aggradation, and incision of "proto-channels" into the bed of steep, shallow ($h/D_{50}<4$) flows. The occurrence of the first of these can be partly predicted using existing criteria for the occurrence of alternating bars. Cut-offs result in the formation of zones of flow convergence (confluences) and divergence (medial bar deposition) whose spacing is similar to that of the wavelength of the prior meanders. The occurrence of alternating bars and the development of avalanche faces on migratory unit bars is subject to control by flow depth and bed shear stress.

Braiding intensity, bed relief and the abundance of avalanche-face bars are all positively correlated with stream power. Greater stream power in excess of the critical value for sediment motion produces a progression from 'proximal' braided stream morphology to one more characteristic of 'distal' braided streams.

Braiding intensity and avalanche-face bar development are also related to regular fluctuations in the sediment transport rate that occur at the scale of a few hours. An increase in the sediment delivery rate to an area of the channel causes aggradation, increased braining and the formation of a greater number of avalanche faces. A given area of the stream undergoes repeated cycles of aggradation and degradation resulting in the transfer of sediment in a series of steps along the channel. Smaller-scale fluctuations in the sediment transport rate, in the form of diffuse sheets and unit bars, are responsible for the step-by-step construction of complex bars and fluctuations in scour depth at confluences. Thus, the process of sediment transport and the morphology of the braided stream are intimately linked.

17. ASHMORE, P.E. and PARKER, G.
    1983: Confluence Scour in Coarse Braided Streams; Water Resources Research, Vol. 19, No. 2, p. 392-402.

ABSTRACT:

Laboratory models of a braided valley flat in coarse material were used in conjunction with field data to study confluence scour at braid anabranches. Correct prediction of the depth of scour is required for the design of buried pipeline crossings. Braid pattern and anabranches constantly shift and avulse so that scour holes have definable lifetimes. Although the scatter is large, the depth of water in the scour hole depends on confluence and relative anabranch discharge; this depth can be as high as six times the ambient depths in the anabranches.

18. BALLANTYNE, C.K.
1975: Geomorphological and Hydrological Investigations in a High Arctic Drainage Basin; Unpublished M.Sc. Thesis, McMaster University, Hamilton, 233 p.

ABSTRACT:

This dissertation reports the results of investigations into the geomorphic role of fluvial processes in a high-arctic glacierized drainage basin in the summer of 1974. A review of the relevant literature (Chapter 1) is followed by a statement of objectives and a description of the study area. In Chapter 3 the drainage network at the time of deglaciation is reconstructed and the subsequent modifications effected by the river are shown to involve downcutting concomitant with isostatic recovery, with the resultant formation of gorges and terracing of alluvial deposits. The three-month hydrologic regime of the river and its major tributaries is described and analysed in Chapter 4. Glacial meltwater is found to constitute 55% of total discharge, snowmelt 35%. Flash floods occurring on the river are explained in terms of the temporary retardation of flow at the glacier margin. In Chapter 5, figures for dissolved and suspended concentrations and load are presented for the river and its major tributaries, and sediment concentration - discharge relationships are described and discussed. Sources of sediment are investigated and results compared with those obtained elsewhere in the arctic. Chapter 6 includes a description of the erosional landforms of the basin, and a detailed analysis of cobble-size distribution over the surface of active and relict sandar from which it is concluded that cross-sandur variations in clast size may be just as significant as downsandur fining. The major conclusions of the study are restated in the final chapter.

19. BALLANTYNE, C.K.
1978: Variations in the Size of Coarse Clastic Particles over the Surface of a Small Sandur, Ellesmere Island, N.W.T., Canada; Sedimentology, Vol. 25, p. 141-147.

ABSTRACT:

For a small sandur in the Canadian Arctic, trend surface analysis of fifty-three samples shows that less than 40% of clast size variation is explained by downsandur fining. Further variations are explained by considering different levels of the sandur surface separately. In the main flow area, which carries water even during periods of low flow, channel deposits are invariably coarser than bar deposits although the difference lessens and overall sorting improves with distance downsandur. The flood surface area, which carries water only during high discharges, is less affected by downsandur fining than the rest of the sandur, and the bar-channel relationship is weaker. The high flood surface which occupies most of the proximal zone of the sandur is probably an abandoned main flow surface, as indicated by clast size characteristics similar to those on the present main flow surface.

20. BEAK CONSULTANTS LIMITED

1978: Arctic Islands Pipeline Project, Water Quality Survey Volume II, Technical Appendices; Report to Arctic Island Pipeline Project, Department of Fisheries and Environment, Water Survey of Canada, Inland Waters Directorate, Winnipeg, 104 p.

ABSTRACT:

Volume II of the Arctic Islands Pipeline Water Quality Study is a compendium of water quality data within each study area as reported by various researchers.

21. BECKSTEAD, G.R.

1978: Reassessment of Degradation and Erosion on the East and West Prairie Rivers; Internal Report River Engineering Branch, Environment Engineering Support Service, Alberta Environment, 77 p. + 3 Appendices.

ABSTRACT:

The following report treats the processes of bed degradation, aggradation and lateral erosion on both the East and West Prairie Rivers. The general bed degradation rate on both rivers has decreased. On the West Prairie River, the maximum possible degradation at the highway bridge is estimated to be to elevation 1912 feet, about 12.7 feet below the present bed elevation of 1924.7 feet. At the highway bridge on the East Prairie River, an additional 12 feet of degradation is forecast to elevation 1913 feet. The time required to complete 95% of the degradation process on both rivers has been estimated through the use of an analytical sediment transport model: East Prairie River - 1979; West Prairie River - 2010. Aggradation has not affected degradation on the West Prairie River but the results of the 1976 survey of the East Prairie River indicate that aggradation in the lower channel reach has initiated deposition in a part of the channelized reach that was previously aggrading. Continued degradation on the West Prairie River will necessitate major reconstruction of the Highway No. 2 bridge, and replacement of the existing N.A.R. crossing. Due to the severe effects of degradation on these structures and property around High Prairie, a need for a grade control structure on the West Prairie River is identified, and consequently recommended. The Highway No. 2 bridge on the East Prairie River has been designed to withstand degradation to 1913 feet. However, additional spans must be added to both the east and west approaches of the N.A.R. crossing. Designs are provided for river training works (pile and timber groynes or riprapped sloped) to control bank erosion upstream and downstream of the bridge crossings. Analysis of historical bank erosion rates on the West Prairie River upstream of High Prairie indicated that channelization has had no effect on erosion in this area. The average annual bank erosion rate was determined to be 8.6 feet per year; the value of average annual loss of land (eight acres per year) is estimated to be about $1800. The potential for flooding on the West Prairie River near High Prairie was analyzed and the chances of this occurring were determined to be rare.

22. **BECKSTEAD, P.**
1980: Travers Reservoir Sedimentation Study; Internal Report, Alberta Department of the Environment, Environmental Engineering Support Services, Technical Services Division, 18 p.

ABSTRACT:

Deposition of sediment in the outlet approach channel of Travers Reservoir has affected the operation of the outlet. Surveyed cross-sections showed that the adjacent cut slope was not the source of the deposited material. Inspections indicated that fine sediment released from shoreline formation upwind might be transported by longsore currents to the outlet area. Sediment sampling in the approach channel and along the reservoir shoreline verified this hypothesis. Theoretical calculations of wind and wave climates, and computer generation of surface were rays demonstrated that littoral currents could be produced along the shoreline. The calculated volume of sediment transported by littoral currents was greater than the amount of deposited sediment indicated by the surveyed cross-sections. A large portion of the sediment was though to have deposited in the deep portions of the reservoir upstream of the outlet approach channel. As sediment transport rates are espected to diminish with increasing shoreline stability, it was forecast that sedimentation in the outlet approach channel will not be as serious as it has been since the reservoir was formed. Therefore, instead of constructing expensive sediment-trapping devices, it was recommended that a maintenance program of dredging the outlet approach channel be undertaken to provide for efficiency operation of the outlet works.

23. **BINDA, G.G.**
1984: Fluvioglacial Sediment and Hydrochemical Dynamics, Peyto Glacier, Alberta: Unpublished M.A. Thesis, Department of Geography, University of Ottawa, Ottawa, Ontario, 139 p.

ABSTRACT:

Hydrological, hydrochemical and suspended-sediment regimes at Peyto Glacier, Alberta (116°33'W, 51°40'N) during the 1981 ablation season showed significant seasonal and diurnal trends.

The seasonal hydrograph (May 19 - September 9) is divided into four components. Initially, during the months of May and June, as glacier snowmelt is retained in the snowpack and in blocked crevasses and conduits, runoff consists of a steady baseflow and snowmelt from nonglacierized areas. A freshet component, in late June and early July, results from a rapid release of meltwaters from major arterial conduits and from the snowpack. During July and August, the main ice ablation component, hydrological events occur in response to precipitation and icemelt events. Peaks in discharge coincide with periods of sustained high temperature or precipitation. A return to a steady baseflow takes place in late August and September as unfavorable climatic conditions curtail icemelt and runoff.

Hydrochemically, the meltwaters are initially "chemically-enriched" as they originate from the "ion-rich" subglacial zone. But as the ablation season progresses, "chemically- dilute" meltwaters from the supraglacial and englacial zones are added to the subglacially routed waters resulting in lowering of the overall concentration by dilution. This dilution effect is also apparent in the electrical conductivity regime. Divalent cations, calcium (Ca^{++}) and magnesium (Mg^{++}) are the most abundant cations in Peyto Creek meltwaters.

The attached cationic concentration displays a seasonal trend in response to changing contact-times within the glacier system. Early and late season concentrations are high because low discharges lead to increased contact-time while the high discharges of July and August result in decreased transit-time and lower concentrations. Calcium (Ca^{++}) is the most readily absorbed cation.

The glacier suspended-sediment regime is very irregular seasonally and diurnally. Greater suspended-sediment concentrations are not linked to proportionally greater discharges and irregular pulses of sediment occur independently of discharge variations. These sudden releases produce peaks which occur both before and after the daily discharge peak. On certain occasions no apparent trend is visible. Thus, subglacial channel re-organisation under changing hydrostatic pressures and sediment availability are hypothesized to be the major factors influencing suspended-sediment output from Peyto Glacier.

24. BINDA, G.G., JOHNSON, P.G. and POWER, J.M.
1985: Glacier Control of Suspended-sediment and Solute Loads in a Rocky Mountain Basin; Proceedings of the Canadian Hydrology Symposium on Water Quality Evolution Within the Hydrological Cycle of Watersheds, University of Laval, Quebec, June 10-12, 1984.

ABSTRACT:

Hydrological, hydrochemical and suspended-sediment regimes at Peyto Glacier, Alberta, (116°15'W, 51°04'N) during the 1981 ablation season showed significant seasonal and diurnal trends.

The seasonal hydrograph (May 19 - September 9) is divided into four components. Initially, during the months of May and June, as glacier snowmelt is retained in the snowpack and in blocked crevasses and conduits, runoff consists of a steady baseflow and snowmelt from non-glacierized areas. A spring freshet component occurs in early July as stream discharges rise suddenly due to rapid release from major arterial conduits and from the snowpack. During July and August, the main ice ablation component, hydrological events occur in response to precipitation and ice-melt events. Peaks in discharge coincide with periods of sustained high temperature or precipitation. A return to a steady baseflow occurs in late August and September as unfavorable climatic conditions curtail ice-melt and runoff.

Hydrochemically, the meltwaters are initially "chemically-enriched" as they originate from the "ion-rich" subglacial zone. But as the ablation season progresses, "chemically- dilute" meltwaters from the supraglacial and englacial zones are added to the subglacially routed waters resulting in lowering of the overall concentration by dilution. This dilution effect is also apparent in the electrical conductivity regime. Divalent cations, calcium (Ca^{++}) and Magnesium (Mg^{++}) are the most abundant cations in Peyto Creek meltwaters.

The glacier suspended-sediment regime is very irregular seasonally and diurnally. Greater suspended-sediment concentrations are not linked to proportionally greater discharges and irregular pulses of sediment occur independently of discharge variations. Subglacial channel re-organisation under changing hydrostatic pressures and sediment availability seem to be the major factors influencing suspended-sediment output from Peyto Glacier.

25. BLACHFORD, D.P.
1982: Spatial and Temporal Trends in the Fluvial Transport of Metals and Phosphorus in the Bow and Oldman Rivers, Alberta; Unpublished M.Sc. Thesis, Department of Geography, Queen's University, Kingston, 242 p. + 8 Appendices.

ABSTRACT:

Conventional water quality monitoring programs depend upon 'total' and where possible 'filterable' contaminant concentrations in water. The present study identified the pathways of metals, phosphorus and organochlorine compounds in water, suspended sediments and plants. Pathway information is evaluated in terms of the ability of conventional water quality information to identify spatial and temporal trends and causality of contaminant stress in the aquatic environment. The study focusses upon the reach of river extending downstream from Calgary on the Bow River and from Lethbridge on the Oldman River to their confluence at Bow Island. Water and suspended sediment samples were collected by hydrologic synoptic sampling during the spring, early summer, summer and fall discharge regimes. Aquatic plants were collected during the summer and fall. Water samples were analyzed by conventional methods for 'total' and 'filterable' metals and phosphorus and were scanned for organochlorine residues. Sediments and plants were analyzed for 'total' metal and for phosphorus species. Conventional measures of 'total' and 'filterable' metals are not able to characterize spatial and temporal changes in concentration. Suspended sediments and plants reflect downstream changes in river chemistry. Plants are useful indicators of the bioavailable component of metal flux. Conventional metal loadings are inaccurate due to large biomass-associated metal loads. Measures of TP and TDP adequately reflect phosphorus trends but do not account for the biomass-associated load. Sediment-phosphorus speciation is required for downstream management purposes in order to characterize the potentially available phosphorus forms. Nutrient abatements programs for the purpose of plant control must be cognizant of rapid luxury consumption, upstream seeding and hydraulic conditions.

26. BLACHFORD, D.P. and ONGLEY, E.D.
1984: Biogeochemical Pathways of Phosphorus, Heavy Metals and Organochlorine Residues in the Bow and Oldman Rivers, Alberta, 1980-1981; Inland Waters Directorate, Environment Canada, Scientific Series No. 138, 35 p.

ABSTRACT:

Spatial and temporal pathways of phosphorus, metals and organochlorine compounds in water, suspended sediments and plants were identified in the Bow and Oldman rivers. Sampling was carried out during the spring, early summer, summer and fall discharge regimes of 1980 and 1981. Seasonality of particle size and organic content was assessed. Pathways information was evaluated in terms of the ability of conventional water quality information to identify patterns and causality of nutrient and contaminant stress in the aquatic ecosystem.

Total and dissolved phosphorus measures characterize seasonal and downstream changes in phosphorus flux. Sediment-phosphorus speciation is required to identify phosphorus forms which are potentially available at downstream locations and at different stages of the hydrologic regime. Aquatic plants accumulate large quantities of phosphorus and represent a load significantly greater than that determined from conventional variables.

Total and filterable concentrations of metals are not useful in identifying spatial and temporal trends. Most filterable levels are below detection limits; total levels that are detactable reflect suspended sediment concentrations and particle size. Sediments and plants do indicate downstream changes in river chemistry. Plants are useful indicators of the available component of metal flux. Metal accumulation in plants implies a major loading which is temporarily held in biomass and which may be of downstream significance after decay of the organic material and consequent release of metals.

Organochlorine compounds associate with one or more of the water, sediment or plant phases. Conventional characterization of the compounds only in the water medium may greatly underestimate their presence.

27. BOBEY, N.
1965: A Field Study of Bed Activity in the Lower Red Deer River; Unpublished M.Sc. Thesis, Department of Civil Engineering, University of Alberta, Edmonton, 48 p.

ABSTRACT:

Quantitative data were obtained in a sand-bed reach of the Red Deer River, Alberta during ordinary summer stage for the study of bed activity and determination of hydraulic characteristics.

The general alternation and deformation of the mobile sand-bed with change in stage is described.

The forms of bed roughness as recorded with sonic sounding equipment and their change with change in stage is given in detail.

The growth and displacement of a scour hole at a sharp bend with rising stage and its subsequent retraction with falling stage is described. A local scour hole near an old truncated bridge pier is also described and discussed.

The regime equations are reviewed. The bed factor and side factor parameters are evaluated and the bed load charge is estimated.

Friction coefficients in terms of the Manning "n" and the Darcy-Weisbach "f" are evaluated for the study length.

28. BODALY, R.A., ROSENBERG, D.M., GABOURY, M.N., HECKY, R.E., NEWBURY, R.W. and PATALAS, K.
1984: Ecological Effects of Hydroelectric Development in Northern Manitoba, Canada: The Churchill-Nelson River Diversion; In: Effects of Pollutants at the Ecosystem Level, P.J. Sheehan, D.R. Miller, G.C. Butler and Ph. Bourdeau editors, John Wiley and Sons Ltd., p. 273-309.

ABSTRACT:

This paper presents the overall features of the Churchill and Nelson Rivers hydroelectric development. It also summarizes the ecological effects of the development and recommends future planning needs for hydroelectric development in subarctic areas.

29. BORNHOLD, B.D.
1975: Suspended Matter in the Southern Beaufort Sea, Beaufort Sea Technical Report #25b, 23 p.

SUMMARY:

Concentrations of suspended matter measured in the southern Beaufort Sea in August and September, 1975 ranged from less than 0.1 mg/L to more than 17 mg/L. The highest concentrations were recorded at nearshore stations off Kugmallit Bay. Mid-water and near-bottom zones of turbid water are common, though their exact causes are not clear.

The distributional pattern of suspended matter reflects closely the physical oceanography of the area. As seen from satellite photographs, the sediment plume from the Mackenzie River is carried eastwards along the inner shelf while the plume emanating from Kugmallit Bay remains as a distinct band of turbid water along the southwestern Tuktoyaktuk Peninsula. The small basin southeast of Herschel Island receives considerable suspended sediment from longshore drift produced by a small clockwise eddy and the easterly flow past Herschel Island. The anticlockwise gyre which flows south and southeastward into Mackenzie Bay, brings little suspended matter into the shelf waters west of Herschel Island.

The major components of the suspended matter include fine inorganic particles, organic aggregates of plankton and inorganic particles, and phytoplankton. Throughout the area the clay minerals display distinct differences. The Mackenzie Bay and outer shelf samples contain montmorillonite, kaolinite and little chlorite and inshore samples off Kugmallit Bay contain no kaolinite or montmorillonite and abundant chlorite.

30. BRADLEY, C. and SMITH, D.G.
1984: Meandering Channel Response to Altered Flow Regime: Milk River, Alberta and Montana; Water Resources Research, Vol. 20, No. 12, p. 1913-1920.

ABSTRACT:

Mean and peak flows, channel width, and rates of meander migration are examined for two sandy meandering reaches of the Milk River in south Alberta and north Montana. One reach, upstream of the international boundary near Onefour, Alberta, is affected by the St. Mary diversion. The other reach near Havre, Montana is below the Fresno Dam and reservoir. Comparisons are possible because of the ample and long-term availability of maps, air photos, and hydrometric records preceding and succeeding the two altered flows for both reaches. Understanding the natural river regime and affects of diversion and dam storage are critical for predicting channel responses to a proposed additional dam on the Milk River. Results indicate that increased discharge due to a diversion has increased channel width 5.5 m and increased the rate of meander migration by 0.85 m/year. Downriver, reservoir storage has decreased channel width 16.8 m and the rate of meander migration by 1.3 m; year and caused channel bed degradation up to 1.5 m near the dam.

31. BRAY, D.I.
1972: Generalized Regime-Type Analysis of Alberta Rivers: Unpublished Ph.D. Thesis, Department of Civil Engineering, University of Alberta, Edmonton, 232 p. + 12 Appendices.

ABSTRACT:

Basic data from 95 gravel and sand-bed river reaches in Alberta, Canada, are utilised in a generalized regime type analysis. Five to ten cross-sections are used to compute average channel properties for each reach. The majority of the slopes are average field slopes based on a reach length of from 10 to 40 channel widths. Reaches are only accepted for analysis if the hydrometric record is at least five years in length. All bed material data for the gravel reaches are based on a grid-by-number analysis. The major part of the analysis is for the 71 gravel-bed reaches.

After considering several definitions of a dominant discharge, the 2 year flood (log-normal distribution) is accepted as the hydrologically defined dominant discharge. The discharge corresponding to the elevation of the valley flat is accepted as the dominant discharge defined by a geomorphic feature.

The equations of Lacey, Blench, Henderson and Kellerhals are tested for the gravel river reaches for the two dominant discharges.

Best fit exponential expressions are developed to predict the width, area, depth, form factor, mean velocity, slope and Manning "n". From one to three parameters are introduced as independent variables in each case. The area-discharge and width-discharge relations are found to be well defined, whereas the slope-discharge relation is highly variable. The implication is that channels essentially are capable of maintaining an orderly cross-section adjustment regardless of the state of the slope adjustment. When a characteristic bed material size is introduced as an independent variable the results based on the median size (DG50) are as good as those for the DG90 size.

The detailed geomorphic description of the reaches are used to stratify the data in an attempt to obtain better results for the slope-discharge relations.

Dimensionless ratios or numerics are developed for the case of a river flowing in deep alluvium. Dimensionless expressions of an exponential form are evaluated and compared with similar expressions obtained from the best fit relations for the gravel reaches. The field data are compared with the dimensionless plots from the Cooper analysis of world flume data.

Eight sets of regime equations for mean width, mean depth, mean velocity, and slope in terms of discharge and median bed material size are developed by considering different sets of three independent equations based on the data for the gravel river reaches. The width, depth, velocity, and slope estimated from the basic form of the Lacey equations, the Kellerhals equations, or a dimensionless set of equations not involving a viscosity term agree quite favourably with the estimates made by using the best fit equations.

32. BRAY, D.I.
1982: Regime Equations for Gravel-bed Rivers; In: Gravel-bed Rivers, R.D. Hey, J.C. Bathurst and C.R. Thorne, Editors, Chichester, Wiley, p. 517-552.

ABSTRACT:

Regime equations for gravel-bed rivers are developed from a data set of 70 gravel-bed river reaches in Alberta, Canada. The 2 year flood flows for this data set range from 195 ft^3/s to 315 000 ft^3/s ($5.52\ m^3s^{-1}$ to $8920\ m^3s^{-1}$). The basis for selecting the 2 year flood flow as a characteristic discharge is presented. Downstream hydraulic geometry relationships are developed and compared with the results of other investigations. The width-discharge and area-discharge relationships are better defined than the slope-discharge relationship. Slope data are stratified by various geomorphological criteria in an attempt to improve the slope-discharge relationship. Entrenched river reaches are found to have a different functional form of the slope-discharge relationship than for the case when all river data are considered. Sinuosity and the island code are used to classify the channel type in a way similar to that of Leopold and Wolman. Form factor-discharge relationships can be related to the dominant type of alluvial bank material. Under the assumption that a gravel-bed channel is free to adjust, four different methods are used to develop regime equations for width, depth, velocity, and slope as power functions of the 2 year flood flow and a characteristic bed material size. Three of the methods are based on some physical reasoning and one method simply involves multiple linear regression. Two of the methods are independent of the Alberta gravel-bed river data but all methods are tested and compared with the same data set. The various regime equations may be used for preliminary design of stable channels for regions having a hydrological regime similar to that of Alberta. The equations must be used with caution when making estimates of changes due to a modification of the water and sediment regime in a basin.

33. BRUNSKILL, G.J.
1974: Sediment Yield from Tributaries to the Mackenzie River, N.W.T., Canada; Geological Society of America, Abstracts with Programs, Vol. 6, No. 7, p. 1025-1026.

ABSTRACT:

Rates of transport of suspended sediments from selected tributaries of the Mackenzie River varied from 0.017 metric tons $km^{-2}yr^{-1}$ (low relief watersheds containing many lakes) to over 100 mt $km^{-2}yr^{-1}$ (high relief watersheds draining the Mackenzie Mountains). The magnitudes of discharge and relief appear to be controlling factors on sediment yield in this region. Approximately 160 x 10^6 metric tons of suspended sediment are delivered to the Mackenzie Delta annually by the Mackenzie and Peel Rivers. The clay-sized sediments are largely illite, chlorite, and amorphous clays, with small proportions of kaolinite and montmorillonite. Cation exchange capacities are low, ranging from 8 to 15 meq/100 g dry weight.

34. BRUNSKILL, G.J., CAMPBELL, P., ELLIOT, S.E.M., GRAHAM, B.W., DENTRY, W.J. and WAGEMANN, R.
1975: The Chemistry, Mineralogy, and Rates of Transport of Sediments in the Mackenzie and Porcupine River Watersheds, N.W.T. and Yukon, 1971-73; Technical Report No. 546, Environment Canada, Forest Management Service, Research and Development Directorate, Winnipeg, 69 p.

ABSTRACT:

Measurements of concentrations of suspended sediments (SS), particulate carbon (PC), particulate nitrogen (PN), particulate phosphorus (PP), and discharge (Q) were made on a variety of large

and small rivers and streams of the Mackenzie Valley and Northern Yukon. Significant logarithmic relationships were found between concentrations of SS, PC, PN, PP, and discharge for each river station studied. Annual sediment and PC, PN, PP transport rates (in tons or moles per sq.km. per year) were also logarithmically related to annual Q for all rivers studied. Suspended sediment transport rates varied between 0.2 and 11.5 mt per sq.km. per year) for small (less than 10,000 sq.km. watershed area) rivers and streams, and 36 to 126 mt per sq.km. per year for large (more than 15,000 sq.km. watershed area) rivers. Multiple linear regression analyses on log transformed data for annual rates of transport of sediments, PC, PN, and PP, and a variety of map derived geographic and climatic parameters indicated that watershed area, forest cover, relief, and precipitation account for over 97% of the differences in rates of transport values among the selected rivers. Rates of transport of suspended sediments in the watersheds studied were similar to data from other arctic and temperate zone watersheds. Equations were developed to allow the estimation of sediment, PC, PN, and PP annual transport rates in unsampled watersheds in the Mackenzie Valley Lowlands. Computed sedimentation rates (3.8 kg sediments per sq.m. per year, 9 moles C per sq.m. per year, 0.3 moles N per sq.m. per year, 0.06 moles P per sq.m. per year, based on Mackenzie and Peel River sediment transport rates) for the Mackenzie Delta and near-delta portions of the Beaufort Sea agree well with analyses of bottom sediment samples in these regions. Bedload transport of cobbles and boulders were estimated in one small stream near Ft. Simpson, and was found to be less than 2 m per year for stones 0.1 kg and larger. Cation exchange capacity of suspended and bottom sediments from rivers and streams was found to be low (8 to 20 meq per 100 g sediment) compared to Mackenzie Delta lake sediment samples (15 to 47 meq per 100 g). The major reactive ions extracted by acid and base were Ca, Mg, Na, and Fe. The major minerals in suspension were quartz, plagioclase, orthoclase, detrital calcite, detrial dolomite, illite, and chlorite.

35. BRUNSKILL, G.J., ELLIOTT, S.E.M. and CAMPBELL, P.
1980: Morphometry, Hydrology and Watershed Data Pertinent to the Limnology of Lake Winnipeg; Canadian Manuscript Report Fisheries and Aquatic Sciences No. 1556, Department of Fisheries and Oceans, Western Region, Winnipeg, 37 p.

ABSTRACT:

Morphometric, hydrologic, and climatic data for Lake Winnipeg and its watershed are given. Over half the annual water supply to the lake comes from eastern Precambrian Shield rivers, which drain only 18% of the total lake watershed. Prairie rivers (which drain sedimentary watersheds), have lower discharges of water, but carry high concentrations of nutrients, salts, and sediments. Theoretical water renewal time for the lake varied from 2.9 to 4.3 years for 1969-1974, depending upon seasonal variations in river discharge. Theoretical water renewal time for the south basin of Lake Winnipeg was computed to be 0.4 to 0.8 years, but interbasin water fluxes due to wind-driven currents are much larger than river discharge into this small basin. With large fetch, abundant wind energy, and shallow water depths, the lake is well mixed vertically. Large horizontal gradients for most limnological parameters were related to the orientation, magnitude, dissolved salt and suspended sediment load of river discharge into the three major basins of the lake. Annual sediment transport (=drainage area erosion rate) for the muddy prairie rivers (Red, Saskatchewan) was 1 to 20 tonnes per sq.km. watershed per yr, which was in the lower part of the range of other North American prairie rivers. Dissolved salt and nutrient transport rates were computed, and were found to be relatively low, compared to other agricultural watersheds. The highest chemical erosion rates were from the Precambrian Shield watershed of the Winnipeg River, which has 5 to 10 times more water runoff than the prairie watersheds. Very low nutrient transport rates were computed for the Saskatchewan River. We tabulated the annual cultural and/or technological supply of N and P to the Lake Winnipeg watershed, using historical and statistical records of human and livestock populations, fertilizer and detergent consumption. Historical trends of human and livestock populations, and land area under cultivation indicate moderate growth, but fertilizer application rates are increasing exponentially. We estimate that 0.5-3.5% of P, and 0.4-0.8% of the N mobilized by agriculture and populations of humans and livestock reaches Lake Winnipeg via rivers. A tentative estimate of chlorinated hydrocarbons and mercury supply rates to Lake Winnipeg was also made.

36. BRUNSKILL, G.J. and GRAHAM, B.W.
1979: The Offshore Sediments of Lake Winnipeg; Fisheries and Marine Service Manuscript Report 1540, 75 p.

ABSTRACT:

Samples of surface sediments of Lake Winnipeg were taken with dredges at 50 stations, and 1 to 2 m cores were taken at 13 stations. Suspended and bottom sediments of the Red River were also obtained. Over 70% of off-shore sediment samples were silty clays or clayey silts. Coarser sediments near shore were not adequately sampled. The major minerals in sediment samples were quartz, feldspars, dolomite, calcite, illite, the montmorillonite group, and chlorite and kaolinite. Water content varied from 27% to 80%. Inorganic carbon (C_1, dolomite and calcite) varied from 83 to 3500 µmoles C_1/g, and organic carbon (C_0) varied from 166 to 3920 µmoles C_0/g. Total phosphorus (ΣP) in sediment samples varied little (13 to 27 µmoles P/g) throughout the lake, whereas total nitrogen (ΣN) varied over a wider range (<7 to 286 µmoles N/g). Dilute acid or buffered NTA extracted 40% to 70% of ΣP in sediments, but the sediment sorbed orthophosphate from solutions at concentrations similar to those of Lake Winnipeg water. Ratios of C_0, ΣN, and ΣP in sediments were not those expected for organic matter, and it is suggested that much of the ΣN and ΣP in Lake Winnipeg sediments is inorganic. Among the major elements of the sediments, Al was most strongly correlated

with the abundance of the clay fraction, Ca and Mg were correlated with C_1 (likely dolomite), and Si was correlated with the large particle sizes (likely quartz and feldspars in sands and silts). Trace elements (V, Cu, Co, Cr, Ni, Be, Cd, Mo, As, Zn, Pb, Sr, Mn) in these sediment samples varied little with location or sediment depth, but small increases in Hg concentrations near the sediment surface of several cores of the south basin were noted. Major and trace element data are also given for Red River suspended sediment, and an estimate of elemental sedimentation rates is given for the south basin of Lake Winnipeg. Major element data are reported for interstitial water squeezed from dredge samples. Sulfate was usually depleted in these interstitial waters, and Ca, Mg, Na, K, Cl, and Si were usually enriched, compared to overlying lake water.

Major basins of sediment accumulation in Lake Winnipeg are designated and described. The Saskatchewan, Cannibal, Mukutawa, Berens, and Black Bear Basins in the northern part of the lake are supplied with sediments primarily from shore and island erosion. The Red River Basin is provided with sediments from the Red River and shore erosion. Sedimentation rates for the Red River Basin ranged from 150 to 1970 g m^{-2} yr^{-1} over 1969-73, and sediment accumulation rates of 0.5 and 0.9 mm yr^{-1} were estimated from sonar penetration and Red River sediment supply rates. Sedimentation rates for C_0, ΣN, ΣP were computed, and were found to lie in the low part of the range for St. Lawrence Great Lakes sedimentation rates. Moment parameters for the particle size distributions of Lake Winnipeg sediment samples were compared to St. Lawrence Great Lakes data. Lake Winnipeg sediments approach a normal distribution of particle sizes, compared to St. Lawrence Great Lakes sediments. This is because most of the sediments supplied to Lake Winnipeg are pre-sorted silts and clays derived from glacial Lake Agassiz sediments.

37. **BRUNSKILL, G.J., ROSENBERG, D.M., SNOW, N.B., VASCOTTO, G.L. and WAGEMANN, R.**

1973: Ecological Studies of Aquatic Systems in the Mackenzie-Porcupine Drainages in Relation to Proposed Pipeline and Highway Developments; Environmental-Social Committee, Northern Pipelines, Task Force on Northern Oil Development, Report Nos. 73-40 and 73-41, Ottawa, 131 p. and 345 p.

ABSTRACT:

Plans and animals that live in rivers, streams and lakes (and the physical and chemical parameters that control their growth and reproduction) are being studied as indicators of aquatic ecosystem sensitivity to disruption by gas and oil pipelines, and road developments in the Mackenzie and Porcupine River Valleys. In 1971-72, Fisheries Research Board staff performed a broad chemical and biological survey to identify the different types of ecosystems and the species of organisms in this vast area. From these data, we selected three areas for more intensive study in 1972-75. These are: Fort Simpson area, being in the discontinuous permafrost region of the upper Mackenzie Valley lowlands; the Mackenzie Delta, a fertile and diverse labyrinth of lakes and channels; and the Porcupine River region west of Old Crow (Yukon), being a biologically unique glacial refogium and an area where local natives are largely dependent upon undisturbed seasonal movements of fish and other wildlife. Chemical laboratories, storage, and field H.Q. are at Yellowknife, and chemical and biological laboratories in the Freshwater Institute are utilized.

The results of our survey work in the study area indicated: 1) naturally turbid, salt-laden rivers and lakes supported a less abundant and diversified invertebrate fauna and flora than did aquatic systems with low concentrations of suspended sediment, 2) there was a decline in abundance and diversity of benthic invertebrates with increasing latitude, 3) that water solution ionic strengths varied from extremely dilute (30 umhos/cm at 25°C) to nearly full strength sea water, 4) that suspended sediment concentrations varied from less than 1 g m^{-3} to over 2,000 g m^{-3}, and 5) that bottom sediments in streams and lakes varied from clay-size to boulder and clean bedrock substrates, with a variety of types of organic matter in the sediment. Natural events related to hydrological cycles and terrain instability caused great fluctuations in the physical and chemical characteristics of water bodies, and their flora and fauna.

To predict the effects of corridor (pipelines and road) development, we have performed controlled experiments in which crude oil was added to a stream in the northern Yukon and a small lake in the Mackenzie Delta. In the Fort Simpson and Inuvik regions, we have utilized disturbances from recent construction of the Mackenzie Highway across stream watersheds as experiments to determine the effects of increased siltation on aquatic ecosystems. Laboratory experimental studies on interactions of oil, silt, dispersing agents, and microbial degradation rates of petroleum products are underway. We have also visited sites of accidental oil spills in Inuvik, Resolute Bay, and Yellowknife Bay to assess the impact of the oil and clean-up activities on aquatic ecosystems. Experimental studies on the effects of increased siltation on lakes and streams are just beginning.

Although our studies are still in progress, we have the following tentative conclusions and recommendations: 1) Increased siltation in a river or lake generally results in decreased abundance and diversity of aquatic organisms. Silt loads in streams will increase during and after construction activities in watersheds. 2) Clear, low-velocity rivers in unstable terrain, and areas where springs occur, should be avoided by corridor development. 3) The effects of crude oil in streams and lakes are rapid (within hours) and often lethal to many aquatic organisms. 4) Existing oil spill contingency plans are not adequate to prevent or even reduce ecosystem disruption. It will be necessary to contain the inevitably spilled oil in a small area to facilitate clean-up and to reduce environmental changes. In streams and rivers, this will be very difficult, and will require the development of new techniques. 5) Bridges are preferred over culverted road crossings in all but the smallest streams. The area of the right of way, and the number of cleared crossing sites (i.e. temporary crossings) should be kept to a minimum. 6) The rate of recovery of oil or silt disturbed aquatic ecosystems is unknown and requires long (5 year) term studies.

38. BRYAN, R.B. and CAMPBELL, I.A.
1980: Sediment Entrainment and Transport During Local Rainstorms in the Steveville Badlands, Alberta; Catena, Vol. 7, p. 51-65.

ABSTRACT:

Patterns of runoff generation and sediment yield in a small badland drainage basin show that localized rainstorms of short duration transport substantial amounts of sediment into the Red Deer River. Experimental plot studies indicate that the threshold precipitation necessary to initiate runoff varies greatly with lithology. Despite lithologic differences, spatial variation in rainfall and highly complex topography, good correlation was noted between sediment yields assessed by different methods. Although great annual and seasonal variations in sediment yield occur, the overall pattern of erosion rates is remarkably consistent.

39. BRYAN, R.B. and CAMPBELL, I.A.
1982: Surface Flow and Erosional Processes in Semiarid Mesoscale Channels and Drainage Basins; Proceedings of Symposium on Recent Developments in the Explanation and Prediction of Erosion and Sediment Yield, EXETER, July 1982, IASH Publication No. 137, p. 123-133.

ABSTRACT:

Detailed studies of surface flow and initiation of channels and drainage networks are facilitated in badlands where barren, rapidly eroded surfaces offer ideal sites for micro and mesoscale experiments. Studies carried out since 1968 in the Dinosaur badlands of Alberta show a considerable range of response in erosion rates and sediment and runoff yields at various scales. At the microscale, the response to desiccated shales depends on the detailed interaction of raindrop impact, particle detachment, surface sealing and sub-surface flow, while indurated sandstones and pediments yield flow and sediment almost instantly, even under low rainfall. The water and sediment flows form a complex system and different response thresholds pose considerable problems for precise monitoring in mesoscale basins.

40. BRYAN, R.B. and HODGES, W.K.
1984: Runoff and Sediment Transport Dynamics in Canadian Badland Micro-Catchments; In: Catchment Experiments in Fluvial Geomorphology, T.P. Burt and D.E. Walling, Editors, p. 115-131.

ABSTRACT:

In this paper, the authors show that surface or subsurface runoff and the timing, duration and volume of runoff discharge are the major factors influencing sediment transport on all lithologies and surfaces. Rainsplash plays an important role in sediment entrainment, but it is not significant in direct sediment transport. Mass wasting is not an important factor is sediment transport except for certain surfaces in specific rainstorms. Experiments show very complex patterns of water and sediment transport and provide an insight into the variable response of mesoscale tributary catchments to typical storm events and into the fluctuating contribution of sediment and water to the Red Deer River.

41. BRYAN, R.B., IMESON, A.C. and CAMPBELL, I.A.
1984: Solute Release and Sediment Entrainment on Microcatchments in Dinosaur Park Badlands, Alberta, Canada; Journal of Hydrology, Vol. 71, No. 1-2, p. 79-106.

ABSTRACT:

This paper first considers the uptake of solutes and entrainment of sediments in runoff generated by simulated rainstorms on different badland surfaces; then, properties of the regolith materials related to solute uptake are described and studied in a number of simple laboratory experiments. Field and laboratory results are in close agreement. Runoff, solute and sediment uptake are profoundly influenced by the large amounts of sodium montmorillonite present in the regolith. Shale surfaces, although responding late to rainfall, release increasing amounts of sediment and solutes (sodium and sulphate) as they swell and increase in erodibility. On other surfaces low rates of rainfall acceptance are caused by the secretion of montmorillonite gels, and there is a gradual decrease in solute and sediment concentration as accumulated salts are flushed from the surface. The effect of the chemistry of the simulated rainfall on the experimental results is examined. It is considered possible to characterize the pattern of solute and sediment uptake on the different badland surfaces and to apply this information to the identification of runoff sources in mesoscale drainage basins and to the routing of storm runoff.

42. CAMPBELL, I.A.
1970: Erosion Rates in the Steveville Badlands, Alberta; Canadian Geographer, Vol. 14, No. 3, p. 202-216.

ABSTRACT:

This paper indicates for one region of western Canada the significance of erosion rates under present processes of landform evolution in a badland environment, and relates the findings to observations from similar regions.

43. CAMPBELL, I.A.
1973: Accelerated Erosion in Badland Environments; Proceedings of the 9th Canadian Hydrology Symposium on Fluvial Processes and Sedimentation, University of Alberta, Edmonton, May 8-9, p. 18-28.

ABSTRACT:

The Red Deer River badlands, a small but rapidly eroding area in the Red Deer drainage basin, are the major sediment source for the river. Data from runoff plots and numerous point measurements indicate that most of the suspended sediment load of the Red Deer within Alberta is derived from the badlands. The observed rates of erosion compare closely to those of analogous areas. Many drainage basins exhibit similar tendencies raising serious problems when computing regional erosion rates based on stream sediment sampling and posing practical difficulties in terms of river and land management.

44. CAMPBELL, I.A.
1974: Measurements of Erosion on Badlands Surfaces: Zeitschrift für Geomorphology, Supplement Number 21, p. 122-137.

ABSTRACT:

The form and erosional characteristics of badlands surfaces in the semi-arid Steveville area of Alberta, Canada, are examined. Field techniques, specially developed, provide data for the construction of computer-plotted contour diagrams on which the results and rates of erosional processes can be shown a time sequence. Although erosion is rapid the surfaces appear to have assumed a form that, within a five year time period, has remained remarkably consistent.

45. CAMPBELL, I.A.
1977: Sediment Origin and Sediment Load in a Semi-arid Drainage Basin; In: Geomorphology in Arid Regions, D.O. Doehring, Editor, Publications in Geomorphology, Fort Collins, p. 165-186.

ABSTRACT:

Sediment origin and suspended sediment load data are examined for the large (43,000 km^2) drainage basin of the Red Deer River in southcentral Alberta. Most of the basin lies within the semi-arid prairie environment though the headwaters are in the moist foothill and mountain section of the province. Fifty percent of the river's mean annual discharge of 70 m^3/s are derived from the headwaters region, or about six percent of the total basin area. The remaining runoff is derived from the prairies. Sediment supply from the headwaters region is comparatively small, accounting for perhaps 12 percent of the total suspended sediment load, and much of the prairie region contributes neither runoff nor sediment to the river. Detailed observations of erosion rates (4.50 mm/yr) and estimates of sediment yield (8,217 tonnes/ km^2/yr) from a region of badlands, that form about two percent of the basin's area, shows these supply about 90 percent of the total suspended load. Parallels are drawn between this situation and the partial area concept of runoff. It is concluded that the common practice of determining regional erosion rates is meaningless.

46. CAMPBELL, I.A.

1977: Stream Discharge, Suspended Sediment, Erosion Rates in the Red Deer River Basin, Alberta, Canada; Proceeding of the Paris Symposium on Erosion and Solid Matter Transport in Inland Waters, July 1977, IAHS-AISH Publication No. 122, p. 244-259.

ABSTRACT:

The study of the relationship between stream discharge and sediment load and regional erosion rates in arid and semiarid environments is greatly complicated by the fact that fluvial activity within the drainage basins of such areas is concentrated in perhaps one or two events each year. Such patterns of fluvial activity present a major problem when attempting to estimate suspended sediment rating curves. In most humid drainage basins much of the sediment load originates with fluvial processes initiated by precipitation, or runoff, over large areas of the basin. High discharges are then usually associated with large sediment loads. Under arid and semiarid climates such situations are rate. Here, intense local convectional rainstorms, often falling on poorly vegetated and highly erodible material close to the channel system, result in large inputs of sediment often accompanied by relatively minor changes in discharge in the main channel. This additional factor further complicates the problem and highlights the general fact that in most drainage systems, in reality, the sediment yield is derived from a relatively small proportion of the total catchment area. In regions of moisture deficiency such a situation almost always pertains. These patterns are illustrated by data collected from the Red Deer River basin, Alberta, Canada. Here, suspended sediment and stream discharge data, as related to surface erosion measurements and regional erosion rates, show that typical rating curves significantly underestimate the occurrence of high sediment concentrations and that in most years the sediment concentrations greatly exceed those computed by rating curves. Such a situation poses potentially severe problems in terms of design criteria for river management projects especially in the arid world.

47. CAMPBELL, I.A.

1978: Local Storms and Sediment Yields in the Steveville Badlands, Alberta; University of Alberta Student Geography Monograph, No. 3, In: Essays on Meteorology and Climatology: In Honour of Richmond W. Longley, K.D. Hage and E.R. Reinelt, Editors, p. 27-39.

ABSTRACT:

Examination of the sediment yield and runoff characteristics of a small catchment in the Red Deer River badlands shows how important local storms are in eroding and transporting the majority of sediment carried into the Red Deer. Investigations in 1968 and 1976 show a high degree of similarity in sediment yield patterns despite an apparently large spatial variation in individual storm activity in any given year. These annual spatial variations appear to even out in the longer term to produce a very consistent pattern of runoff and erosion that is such greater than the regional climatic pattern would suggest.

48. CAMPBELL, I.A.
1982: Surface Morphology and Rates of Change During a Ten-year Period in the Alberta Badlands; In: Badland Geomorphology and Piping, R. Bryan and A. Yair, Editors, Geo Books, Norwich, p. 221-238.

ABSTRACT:

This paper examines ten years of field measured data from an area of badlands in Dinosaur Provincial Park, Alberta, and describes the changes in surface morphology that occurred within the period 1969-1979. The data were collected from nine one-metre square surfaces on a representative sample of slope and lithological units using a portable frame device. Twenty-five measurements from within each 1 m^2 area were taken twice each year for ten years to give a total of 4500 measurements. Each measurement is exact to ± 0.5 mm; surface changes are therefore precisely monitored, and it is possible to assess the rate and form of surface changes by both degradation and aggradation in an open system.

49. CAMPBELL, P., DENTRY, J., MORDEN, G.W., ELLIOTT, S., BRUNSKILL, G.J., WAGEMANN, R. and GRAHAM, B.W.
1975: General Physical and Chemical Data for Water and Sediment of the Mackenzie and Porcupine Watersheds and Rates of Transport of Dissolved and Suspended Elements at Selected Stations in the Mackenzie and Porcupine Watersheds, 1971-74; Fisheries and Marine Service, Research and Development Directorate, Technical Report No. 556, PART 1 and PART 2, 395 p. (PART 1, p. 1-302. PART 2, p. 303-395).

ABSTRACT:

A compilation was made of physical and chemical data on river, stream and lake waters, bottom, shore and bank sediments and rates of transport of dissolved and suspended elements at selected stations in the Mackenzie and Porcupine watersheds during 1971-1974.

50. CAMPBELL, P. and ELLIOTT, S.
1975: Assessment of Centrifugation and Filtration as Methods for Determining Low Concentrations of Suspended Sediment in Natural Waters. Technical Report No. 545, Environment Canada, Forest Management Service, Research and Development Directorate, Winnipeg, 18 p.

ABSTRACT:

An investigation was carried out to determine if concentrations of less than 10 mg per l suspended sediment could be reliably measured in natural waters. Centrifugation of even relatively large (20 liter) volumes of water resulted in highly variable suspended sediment concentrations. Poor precision also resulted when concentrations of suspended sediment were determined after filtering 1 liter aliquots taken from a 20 liter sample. It was shown that in large samples a stratification of suspended sediment resulted within hours of collection. Vigorous shaking before removing an aliquot was not sufficient to homogenize the sample. Filtration of 1 or 2 liter samples, however, produced a precision of better than plus or minus 5% at levels of 2 to 3 mg per l suspended sediment. This high precision was attained irrespective or whether filters were dried to constant weight by desiccation or in an over at 90 to 95 C.

51. CANT, D.J.
1977: Braided Stream Sedimentation in the South Saskatchewan River; Unpublished Ph.D. Thesis, McMaster University, Hamilton, 246 p.

ABSTRACT:

In the study area, the South Saskatchewan River has a sandy bed (mean diameter .3 mm) with irregularly-shaped braid bars termed sand flats. These range in length from 50 to 2000 m. The river has an average discharge of 220 m^3/sec, with a mean annual flood of 1450 m^3/sec. The river has been dammed upstream of the study area since 1965, but little downcutting has occurred.

Ripples, sand waves and dunes are the equilibrium bedforms present. Ripples and dunes are well known, but sand waves are long, low bedforms with superimposed ripples, lack scour troughs, and occur at lower flow velocities than dunes. Foreset-type bars are also present, but are not equilibrium forms. They result from flow expansion around older topography. They occur at (1) channel junctions, (2) channel bends, (3) areas of channel widening, (4) places of vertical flow expansion. They deposit planar crossbeds.

Large areas of the river have many sand flats with no major channels, and may even lack minor channels. These areas are termed sand flat complexes. Where a major channel curves around a sand flat complex, a large diagonal bar is deposited. It is mainly on the tops of these bars where new sand flats form.

The major channels rarely exceed 5 m in depth, but may be 150 m wide. They are floored by sinuous-crested dunes with sand waves and ripples along their margins. The dunes build up during floods (2 m maximum amplitude). Larger dunes occur in the deeper channels.

Three different morphologies of small sand flats, symmetric, asymmetric and side, have been recognized. Each type forms from a bar which becomes partly immobilized where it becomes emergent.

The remainder of the bar front continues to advance around this emergent nucleus. The different morphologies result because of the control exerted by preexisting deposits on the shape of the initial bar.

Larger sand flats lack these morphologies because they have been extensively modified. The major processes of modification are vertical, laterial, and upstream accretion by bars; linking of sand flats by bars; erosional action. The variable morphologies of larger sand flats reflect only their latest modification. The stratification of sand flats is mainly planar crossbed sets deposited by the bars.

During the winter, a 60 cm thick layer of ice covers the entire system. The sand flats are immobilized because their top layers of sediments are frozen. In some places, their surfaces are disrupted by fluid escape caused by high pore pressures generated by freezing. Flow proceeds down the channels under the ice. Rafting of cobbles and scouring around grounded ice blocks takes place at breakup.

The facies sequences resulting from sedimentation in the river are mainly sandy. Those which are deposited by channels consist dominantly of trough crossbeds, but lone planar crossbed sets may be present; deposited by large bars. Facies sequences which include sand flat deposits have several sets of planar crossbeds stacked on top of one another. All sequences have a zone of small crossbeds and ripple cross-lamination near the tops, resulting from shallow water deposition. They are capped by one-half metre of muddy floodplain deposits.

52. CANT, D.J.
1978: Development of a Facies Model for Sandy Braided River Sedimentation: Comparison of the South Saskatchewan River and the Battery Point Formation; In: Fluvial Sedimentology, A.D. Miall, Editor, Canadian Society of Petroleum Geologist, Memoir No. 5, p. 627-639.

ABSTRACT:

Detailed comparisons of individual facies and independently constructed facies sequences in the Devonian Battery Point Formation (BP) of Quebec and the South Saskatchewan River (SS) reveal both similarities and differences.

At the bottom of the summary facies sequence (BP) which was derived by Markov analysis, trough crossbeds correspond to the deposits of dunes in the deeper channels (SS). Solitary planar crossbed sets (BP) with paleocurrent directions which diverse from those of the trough crossbeds are analogous to deposits of oblique slipface-bounded bars in the channels (SS). Cosets of up to 4 sets of planar crossbeds (BP) resemble the stratification of complex sand flats (SS). Small planar crossbed sets near the top of the sequence (BP) correspond to deposits of sand waves, common in

shallow areas of the river (SS). Interbedded mudstone and rippled sandstone near the top of the sequence (BP) resemble the fine-grained cohesive floodplain deposits (SS). Some asymmetric scour fillings and low-angle cross-stratified deposits (BP) are unlike any sediment in the river (SS).

The vertical arrangement of channels, sand flats, and floodplains in the river suggests facies sequences which are similar to the summary sequence (BP). Some observed sequences (BP) are more complex, reflecting rapid aggradation in the channels of the Battery Point river which promoted lateral migration of shallow channels over bars and sand flats.

A facies model for this type of sedimentation consists mainly of channel, bar, and sand flat deposits interfingering laterally and succeeding one another vertically. Minor amounts of cohesive floodplain sediments are also present. Lateral migration of the river back and forth while aggrading causes deposition of a sheet sand elongated parallel to the paleoflow.

53. CANT, D.J.
1978: Bedforms and Bar Types in the South Saskatchewan River; Journal of Sedimentary Petrology, Vol. 48, No. 4, p. 1321-1330.

ABSTRACT:

In the sandy, braided South Saskatchewan River, ripples, sand waves, and dunes are recognized as lower flow regime bedforms on the basis of a morphological classification. Sand waves are straight-crested to rhomboidal and are very regular in the direction transverse to flow, lacking scour troughs or spurs. The amplitudes of sand waves may gradually increase or decrease along their crestlines, but abrupt changes are rare. Dunes are sinuous to strongly three-dimensional bedforms, showing marked irregularities in crestline height and well developed spurs and scour troughs.

Sand waves occur with ripples superimposed on their stoss sides at flow velocities less than 0.5-0.7 m/sec depending on depth. Dunes occur in most cases with no superimposed ripples at velocities greater than sand waves for each depth.

Slipface-bounded bars up to 3 m in height form where the flow is non-uniform and expands laterally or vertically. This happens where channels widen or bend or where the flow passes over an abrupt downward step such as the junction of channels of different depths. Bars may have ripples, sand waves, or dunes superimposed on their upper surfaces and are less sensitive to changing flow conditions than are these others.

Sand flats are large-scale sandy braid bars which are complexes of all the smaller forms. They are comparable in scale to the point bars of meandering streams.

54. CANT, D.J. and WALKER, R.G.
1978: Fluvial Processes and Facies Sequences in the Sandy Braided South Saskatchewan River, Canada; Sedimentology, Vol. 25, p. 625-648.

ABSTRACT:

The South Saskatchewan River has a long term average discharge of 175 m^3/sec, with flood peaks in the range of 1500 to 3800 m^3/sec. South of Saskatoon, the four major types of geomorphological elements recognized are channels, slipface-bounded bars, sand flats and vegetated islands and floodplains. Major channels are 3-5 m deep, up to 200 m wide, and flow around sand flats which are 50-2000 m long, and around vegetated islands up to 1 km long. At areas of flow expansion, long straight-crested cross-channel bars form. During falling stage, a small part of the crest of the cross-channel bar may become emergent, and act as a nucleus for downstream and lateral growth of a new sand flat.

The dominant channel bedforms are dunes, which deposit trough cross bedding. Cross-channel bars deposit large sets of planar tabular cross bedding. Sand flats that flow from a nucleus on a cross-channel bar are mostly composed of smaller planar tabular sets, with some parallel lamination, trough cross-bedding, and ripple cross-lamination. A typical facies sequence related to sand flat growth would consist of in-channel trough cross-bedding, overlain by a large (1-2 m) planar tabular set (cross-channel bar), overlain in turn by a complex association mostly of small planar tabular cross-beds, trough cross-beds are ripple cross-lamination.

By contrast, a second stratigraphic sequence can be proposed, related only to channel aggradation. It would consist dominantly of trough cross-beds, decreasing in scale upward, and possible interrupted by isolated sets of planar tabular cross-bedding if a cross-channel bar formed, but failed to grow into a sand flat. During final filling of the channel, ripple cross-lamination and thin clay layers may be deposited. In the S. Saskatchewan, these sequences are a minimum of 5 m thick, and are overlain by 0.5-1 m of silty and muddy vertical accretion deposits.

55. CHURCH, M.
1972: Baffin Island Sandurs: A Study of Arctic Fluvial Processes; Geological Survey of Canada, Bulletin 216, 308 p.

ABSTRACT:

Valley sandurs form the major postglacial physiographic feature in much of the Canadian Arctic. The conditions favourable for sandur development: presence of an abundant supply of detrital material and the occurrence of relatively frequent floods competent to move the material, are characteristic of proglacial and some periglacial environments.

Nival floods, summer icemelt floods, and summer storm runoff generate significant sediment transport events. Storm runoff is particularly effective in the Arctic since there is little vegetation and the substrate is frozen, so that a high proportion of rainfall runs off immediately. The distribution of runoff events shows a disproportionate number of moderately high flows. Occasionally, extreme floods occur, produced by catastrophic drainage of ponded water from ice margins.

Sediment is transported mainly as bedload, though solution and suspended load are significant. Transport is much greater than the rate of primary detritus production as large volumes of glacially derived material are being redistributed.

Sandur streams are wide and shallow, a characteristic of channels in which most sediment moves as bedload. The major hydraulic adjustment to increasing discharge is made by stream velocity, indicating a change in bed form associated with the rapid increase of sediment transport that results in a sharp decline in flow resistance.

The long profiles of the streams are approximately parabolic; this form is probably conditioned by the nature of the aggradation on the surface as a whole. The sequence of pools and riffles along the channels constitutes a fundamental feature of the river. It appears to function as a regulator of energy expenditure in the stream and concomitantly influences flow resistance and the movement and storage of sediment.

The sandur surface is an aggradational feature. Erosion and deposition occur over wide areas during major floods. Change of stage is rapid so that deposition is often chaotic, and little internal structure occurs in many sediments. Significant pattern is found only in the mean size and variance of coarse materials (cobbles), indicating deposition under conditions of declining competence down sandur.

56. CHURCH, M.
1974: On the Quality of Some Waters on Baffin Island, Northwest Territories; Canadian Journal of Earth Sciences, Vol. 11, p. 1676-1688.

ABSTRACT:

In glacierized and nonglacierized river basins in eastern and central Baffin Island, waters are generally very soft (total dissolved solids of order 5-50 mg/l). Diurnal and seasonal fluctuations in dissolved solids concentration are relared to runoff characteristics and sources.

57. CHURCH, M. and GILBERT, R.
1975: Proglacial Fluvial and Lacustrine Environments; In: Glaciofluvial and Glaciolacustrine Sedimentation, Editors A.V. Jopling and B.C. McDonald, Society of Economic Paleontologists and Mineralogists, Special Publication No. 23, p. 22-100.

ABSTRACT:

This paper reviews the hydrology and hydraulics of high energy, particularly proglacial, riverine and deltaic environments, and discusses some of the consequences for resultant patterns of sediment movement and deposition.

The hydrology of proglacial rivers is under strong thermal influence and exhibits a singular pattern of flow, both seasonally and diurnally. Moderate flood flows are common. Sediment is frequently entrained and deposited, so that rapid evolution of fluvial sedimentary features occurs on outwash plains. The possibility exists for extraordinary jõkullhlaup floods to occur in front of many glaciers. The hydraulic behaviour of proglacial rivers features frequent upper regime flow and rapid adjustment of channel resistance to accommodate the wide variations in discharge and sediment transport.

Sediment entrainment is reviewed in some detail, and the concepts of "overloose" and "underloose" boundary are introduced. Sediment transport theory is reviewed and recommendations made for assessing total sediment yield. The sediment transport in proglacial rivers is anomalously high by comparison with that in nonglacial environments, because of the large volumes of drift delivered to the glacier margin. Flood deposits on outwash plains and surficial patterns of sediment texture are described. The character of the surface is conditioned by selective deposition of sediment in a simple, aggradational context.

Depositional bedforms are classified as small forms (scale controlled by flow depth or lesser flow dimensions) and large forms (scale controlled by channel width). The former reflect puprely local flow conditions, whereas the latter are influenced by the total flow pattern of the river. The persistence of bedforms as sedimentary structures in the stratigraphical record is considered. Gravels commonly exhibit only rudimentary plane bedding and imbrication, whereas fine materials commonly feature a wide variety of sedimentary structures. This is a consequence of the vertical distance available for deposition as compared to particle size, and the energy status of the depositional environment.

River channels in coarse, noncohesive materials are wide and shallow, so that boundary resistance to flow is high. When large volumes of sediment are being transported in flood, total resistance may become too high to permit passage of the water plus sediment load; deposition and selective scour then produce narrower, deeper channels that are hydraulically more efficient. The morphological result is the occurrence of channel braiding, which is a frequent characteristic on outwash. The long profiles of proglacial rivers and outwash surfaces are concave upward as a consequence of persistent aggradation.

Where proglacial rivers enter standing water bodies, classical, high-angle deltas develop. Sediment transported as bed load is deposited on the delta surface, or is deposited on the foreset wedge by avalanching over the delta lip. Turbidity flows (underflows) and slumps move coarse material farther into the water body. Fine-grained material is carried in suspension into the standing water and settles to the bottom to form varves.

Examples illustrating the application of principles and characteristic conditions are drawn from the literature on glaciofluvial and glaciolacustrine environments.

58. CHURCH, M. and KELLERHALS, R.
1978: On the Statistics of Grain Size Variation Along a Gravel River; Canadian Journal of Earth Sciences, Vol. 15, p. 1151-1160.

ABSTRACT:

A suite of 78 samples of riverbed gravel obtained at 39 sites along a 140 km reach of Peace River was used in a statistical study of the behaviour of mean grain size downstream. Whilst the exponential decline described by Sternberg was found in the overall data, significant additional 'structure' was also present. Although efforts were made to ensure that a homogeneous set of samples was obtained in the field, large site scale variability in the data prevented the complete elucidation of the additional pattern, which is probably due to injection of new material at tributary junctions. The paper illustrates sampling criteria that must be met for adequate description of grain size variations along a gravel river and identifies constraints that may limit its achievement.

59. CHURCH, M. and RYDER, J.M.
1972: Paraglacial Sedimentation: A Consideration of Fluvial Processes Conditioned by Glaciation; Geological Society of America Bulletin, Vol. 83, p. 3059-3072.

ABSTRACT:

Glaciation is schematically considered as a perturbation of "normal" fluvial conditions. Drift is unstable in a proglacial or postglacial fluvial environment, resulting in heightened sediment movement that continues as long as drift material remains easily accessible for fluvial erosion and transportation. Sediment yield bears no relation to concurrent primary production of weathered debris.

Examples of such "paraglacial" denudation and sedimentation are reported from two contrasting areas. Postglacial valley alluvial deposits are widespread in central Baffin Island where rapid sedimentation continues today; estimated denudation rates are an order of magnitude higher than in comparable unperturbed areas. In south-central British Columbia, rapid sedimentation during the paraglacial period contrasts sharply with present-day conditions.

60. CHYURLIA, J.
1973: Report on the Stability of River Banks and Slopes Along the Liard River and Mackenzie River, Northwest Territories; Hydrologic Aspects of Northern Pipeline Development, Environmental-Social Committee, Northern Pipelines, Task Force on Northern Oil Development, Report No. 73-3. p. 113-152.

ABSTRACT:

This report provides the results on the investigation of the stability of river banks in the Mackenzie River Basin. Two sites were chosen: 1) the area around Fort Simpson which includes the lower reaches of the Liard River and 2) a stretch of the Mackenzie River from Little Chicago to the settlement of Arctic Red River. Results show that in the case of steep colluvial slopes, the infinite slope model may provide to be adequate in the prediction of stability and that ice content in glacio-lacustrine deposits is the critical variable of mudflows and retrogressive slides.

61. COAKLEY, J.P. and HAMBLIN, P.F.
1964: Investigation of Bank Erosion and Nearshore Sedimentation in Lake Diefenbaker; Internal Report, Canada Centre for Inland Waters, 18 p.

ABSTRACT:

A reconnaissance survey confined largely to the lower reaches of Lake Diefenbaker, Saskatchewan, indicated that shore erosion, though intense, occurs mainly in areas of higher elevation and relief. Most erosion is due to gravity slumping of structurally weakened banks and the material is transported towards the offshore central portions of the reservoir. During the survey, current velocities measured by means of drogues in the area were consistently very low.

62. COAKLEY, J.P. and RUST, B.R.
1968: Sedimentation in an Arctic Lake; Journal of Sedimentary Petrology, Vol. 38, No. 4, p. 1290-1300.

ABSTRACT:

Stanwell-Fletcher Lake is 400 miles north of the Arctic Circle, covers 131 square miles, and is over 100 m deep. Its size and the severe climate restrict summer melting of ice to the margins. The ice insulates the water, which remains essentially isothermal, warming slightly from 1.3 to 1.6°C during the summer. Inflowing water is nearer 4°C, and therefore sinks and mixes with the lake water, a process which maintains thermal and chemical homogeneity in the lake and oxygenates the surficial bottom sediment.

Sedimentation is very slow because of the short period of stream flow and the low organic activity in the lake. Silty sand derived from river bed loads accumulates on shallow marginal deltas and shelves. The sediment is poorly sorted because ice cover prevents wave action and removal of the fine material to deeper water. Mud, derived largely from the suspended loads of rivers, settles slowly in the central part of the lake. Faint laminae in the shelf sands may be varves, but the deep mud is structureless. Evidently seasonal sedimentary variations do not affect the center of the lake, probably because ice cover minimizes transporting currents.

The oxidation-reduction boundary in the sediment is at 5-20 cm, deeper than in temperate lakes, because of oxidation at the lake bottom and slower reduction within the sediment.

63. CULP, J.M. and DAVIES, R.W.
1982: Analysis on Longitudinal Zonation and the River Continuum Concept in the Oldman-South Saskatchewan River System; Canadian Journal of Fisheries and Aquatic Sciences, Vol. 39, No. 9, p. 1258-1266.

ABSTRACT:

During the summer-fall periods, the benthic macroinvertebrate communities of the Oldman-South Saskatchewan River system demonstrated a longitudinal zonation related to the subalpine forest, fescue prairie, and mixed prairie terrestrial ecosystems through which it flows. This zonation was primarily attributable to significant downstream increases in periphyton biomass, plant nutrients, and water temperature. Zonation was reduced in the late winter-spring periods and absent in May, during spring runoff. Longitudinal trends in macroinvertebrates functional feeding groups generally followed the predictions of the river continuum concept, with trophic composition apparently more strongly affected by autotrophic processes in the summer, and heterotrophic processes in the winter. By combining the river continuum concept with a watershed classification system based on geology, climate, soil type, and terrestrial vegetation, we suggest that biological comparisons of longitudinal zonation are enhanced.

64. DAVIES, K.F.
1973: Hydrometric Data Collection in the Mackenzie River Basin; Environmental-Social Committee Northern Pipelines, Task Force on Northern Oil Development, Report No. 73-5, 82 p.

ABSTRACT:

This report outlines the operations of Water Survey of Canada in the Mackenzie Valley area, with particular emphasis on the period since the inception of the Environmental-Social Program, Northern Pipelines.

Prior to 1971 work in the Mackenzie Valley area by Water Survey of Canada was limited. During 1971 and 1972, ten stream gauging stations were constructed at various locations along the Mackenzie River and some of its tributaries. This brings the total number of stations in the Mackenzie Valley area to twenty-six. Eight of the gauging stations are stage only for navigation purposes. Stage and discharge data are collected at the remaining eighteen.

Sediment discharge data collection was commenced in 1972 at nine locations throughout the study area.

Measurement techniques have been changed to meet the needs of the large rivers. Tellurometers are being utilized for distance measuring, and echo sounders for depth measuring. The ERTS satellite system set up in the 1970's is being utilized to transmit stage data to Calgary from northern locations for use in navigation forecasts along the Mackenzie Waterway.

The present network of hydrometric stations in the Mackenzie area is not sufficient to supply the necessary data required for engineering designs on all streams by conventional methods. Correlations of flow rates between the gauged and ungauged areas have been attempted with limited success. These design problems as well as the chemical and biological studies underway that require hydrometric data will have to rely on theoretical methods to satisfy their requirements for flow data.

65. DAVIES, K.F.

1974: Hydrometric Data Summary, Mackenzie River Basin, 1973; Environmental-Social Committee Northern Pipelines, Task Force on Northern Oil Development, Report No. 74-8, 84 p.

ABSTRACT:

This report is an update of the June 1973 report, "Hydrometric Data Collection in the Mackenzie River Basin." The methods of data collection and general discussion as outlined in the previous report are still applicable to the current report. They will not, however, be restated in this volume. The reader is requested to acquaint himself with the previous report in order to obtain this background information.

The purpose of the current report is to present a summary of the streamflow, suspended sediment and related data that were collected during the 1973 calendar year in a useable format and sooner than it would be available through normal publication routes.

All data contained in this report are provisional, subject to correction, pending publication in the Annual Departmental Reports.

66. DAVIES, K.F.

1975: Mackenzie River Input to the Beaufort Sea; Beaufort Sea Project, Technical Report #15, 72 p.

ABSTRACT:

This report contains a summary of the findings under the study, "Mackenzie River Input to the Beaufort Sea," one of a series of studies comprising the Beaufort Sea Project.

Comprehensive descriptions of the gauging sites and methods used are included in the report. Distribution of flow in the main channels as a percentage of total flow has been determined on a month-by-month basis for the period July 1974 to June 1975.

Suspended sediment transport, ice thickness, and water temperature in the Delta are also discussed and the results shown.

All data contained in the report are provisional, subject to correction, pending publication in the Annual Departmental Reports.

67. DAWSON, M.
1982: Sediment Variation in a Braided Reach of Sunwapta River, Alberta; Unpublished M.Sc. Thesis, Department of Geography, University of Alberta, Edmonton, 186 p.

ABSTRACT:

Statistical analyses of downstream grain size variations in an 11 km braided reach of the Sunwapta River shows that there are significant deviations from the theoretical model of an exponential decline in grain size downstream (Sternberg, 1875). Two sources of variation from the expected relationship may be determined variability between sub-reaches and variability within sampling transects. The former source of variability can be attributed not only to the effect of tributary inputs but also to differential rates of aggradation and degradation within and between the sub-reaches. Where there is a tributary input of coarse sediment three principal effects may be noted:

1) Bedslope decreases upstream and increases downstream of the tributary.
2) Grain size increases downstream of the tributary.
3) Diminution rates increase both upstream and downstream of the tributary.

The cause of the variation within sampling transects cannot be identified by statistical methods, but, examination of grain size differences over small braid bars indicates that this is the result of essentially random site-scale factors. The variability demonstrated for the downstream changes in grain size suggests that caution should be used in applying proximal to distal interpretations of fluvial gravel deposits. Diminution coefficients for distinctive lithologies in the reach are anomalous in that the quartzites demonstrate greater values than the limestones. This anomaly is tentatively ascribed to a greater rate of breakage for quartzite clasts and the lag deposition of a coarse quartzite input at the head of the reach. In conjunction with morphological evidence the diminution coefficients show that in the proximal areas of the reach, limited degradation is occurring. In more distal areas higher values for the diminution coefficients indicate that there is limited aggradation. Sediment sorting improves downstream with two trends being identifiable upstream and downstream of the major tributary, Diadem Creek.

Clast roundness increases rapidly in the initial 1 km away from the head of the reach and away from Diadem Creek. Upstream of Diadem Creek the variation in the data is probably best approximated by two separate functions describing the initial, rapid, increase in roundness and the downstream, less rapid, change in roundness. Evidence of trends in other measures of clast morphology is unconvincing, except downstream of Diadem Creek. This is at variance with some other field studies (Bradley et al. 1972) which have shown distinctive relationships.

Mapping of grain size variation on selected braid bars in the gravel permitted the development of a model of braid bar development with three essential elements:

1) The formation of a nucleus by in-channel deposition or the delimitation of the bar outline by channel migration and avulsion.

2) The secondary modification of the original area by lateral accretion and overbank flow.

3) The limited, tertiary modification of the surface by small overbank flows at later high flow stages.

It is suggested that many of the sorting trends on braid bars are the results of the reorganization of previously emplaced sediments by overbank, flow and that, in general, braid bars show a sediment fining downstream and away from active channels.

68. DAY, T.J. and SPITZER, M.O.
1985: Sediment Station Analysis: Highwood River Near the Mouth, 05BL024, Calgary WRB, Western and Northern Region; Internal Report, Sediment Survey Section, Inland Waters Directorate, Environment Canada, 208 p.

ABSTRACT:

Sediment data were collected at the hydrometric gauging station site, "Highwood River near the Mouth" during the period 1970 to 1981 inclusive. The data were primarily suspended sediment, but include bed material as well. This report documents the collected data and treats it in various tabular, graphical and statistical ways. It also contains a basin description and number of photographs taken in the immediate vicinity of the gauging station.

69. DAY, T.J. and SPITZER, M.O.
1985: Sediment Station Analysis: Oldman River Near Brocket, 05AA024, Water Resources Branch, Alberta Region; Internal Report, Sediment Survey Section, Inland Waters Directorate, Environment Canada, 214 p.

ABSTRACT:

Suspended sediment data were collected at the hydrometric gauging station site "Oldman River near Brocket" during the period 1966 to 1983, inclusive. This report documents these data and presents it in various tabular, graphical and statistical ways. The report also contains a description of the basin, a description of the reach in the vicinity of the gauging station, bed material data and a number of photographs taken in the vicinity of the gauging station.

70. De MARCH, L.
1978: Permanent Sedimentation of Nitrogen, Phosphous, and Organic Carbon in a High Arctic Lake. Journal of the Fisheries Research Board of Canada, Vol. 35, No. 8, p. 1089-1094.

ABSTRACT:

The sediments of Char Lake, Resolute, Northwest Territories, were studied to determine storage rates of nitrogen, phosphorus, and organic carbon which could be compared with retention estimates of N and P and primary production and respiration estimates for organic C. The storage rate for P ... was 129% of measured retention, storage of N ... was 43% of measured retention, and the ... storage estimate for organic C was 18% of the difference between primary production and respiration. Lacustrine sediments were found to be very unevenly distributed with accumulations from 7 cm to an estimated 3 m in the last 6200 yr and to vary in N, P, and organic C concentrations from place to place.

71. DEPARTMENT OF FISHERIES AND FORESTRY
1971: Effects of Diversion on the Morphology of the Athabasca-Peace-Mackenzie System; Internal Report, Sediment Survey Section, Water Survey of Canada, Inland Waters Branch, Ottawa, 38 p.

ABSTRACT:

This report provides a preliminary evaluation of the morphological effects of a proposed diversion of Athabasca-Peace-Mackenzie waters to the South Saskatchewan river basin. The report contains a general indication of the effects which the various diversion proposals would have on the morphology of the rivers and lakes involved. Recommendations for a comprehensive hydrological and sediment transport study to be carried out in order to adequately assess the impacts on the different river regimes is put forward.

72. DEPARTMENT OF THE ENVIRONMENT
1967: Delta Formation and Sedimentation in Lake Diefenbaker; Progress Report 1964-67, IHD Project Saskatchewan-2, 12 p. Prepared Jointly by Inland Water Branch and Saskatchewan Water Resources Commission Hydrology Division.

ABSTRACT:

In an average year, the South Saskatchewan River carries an estimated 6,000 acre-feet of sediment. With a detention storage time of many months, most, if not all of this sediment, will be deposited in the 7.6 million acre-foot, 140-mile long reservoir known as Lake Diefenbaker. Although the amount of sediment is not large enough to affect the usefulness of the reservoir in the foreseeable future, it is espected to deposit in the form of a delta extending a considerable distance into the reservoir and for a number of miles upstream. A different though related problem concerns reservoir infilling due to erosion and slumping along the 500 miles of reservoir shoreline. These problems will affect shoreline planning and development, the design and maintenance of structures and the efficient operation of the reservoir.

In consideration of these problems, some studies were undertaken by consultants several years ago. However, the problems are very complex, and it was felt that the results of these theoretical studies should be substantiated and that the studies should be expanded upon by the collection and analysis of field data over a period of years. Accordingly, in 1963, Saskatchewan implemented a program to systematically study the progress, configuration and effect of delta formation and sedimentation which will occur in Lake Diefenbaker. In 1964, this program was designated IHD Project Sask-2.

The type of program that has been developed consists of a system of 38 ranges or cross-sections, which are defined by permanent markers on each bank, and which cross the reservoir and for about 20 miles upstream at chosen intervals. These ranges are systematically surveyed and sounded to obtain profiles across the reservoir and river bed, and suspended sediment and bed material samples are collected at selected locations with the aid of the Inland Waters Branch. Another important component of this project is a program of low-level, aerial photography of the upper reservoir area, particularly at low reservoir levels. Concern over the high water levels which might be attained at the upper end of the reservoir led in 1966 to the addition of a backwater curve study which provides for the collection of data to define water surface profiles for various peak flows. The overall sedimentation program requires annual range maintenance, field surveys and data collection, and office studies to process and analyse the data collected in the field and to prepare reports.

This report summarizes the work that has been undertaken on this project during the four-year period 1964 through 1967. It replaces and updates a previous unpublished report entitled "Sediment Range Programs On and Downstream of the South Saskatchewan Reservoir" dated December 22, 1966, prepared by Saskatchewan Water Resources Commission. The latter report, in a single volume, contains information for both the South Saskatchewan River sediment range program below Gardiner Dam and the program for Lake Diefenbaker. The river range program has been designated IHD Sask-1. A comprehensive report on this study has already been published.

Figures 27 to 64 of this report show profiles across the reservoir. Because they are large and bulky, these figures are not included in all copies of this report. If they are required for a particular purpose, they may be obtained from the Water Survey of Canada or the Saskatchewan Water Resources Commission.

NOTE: THIS REPORT WAS PUBLISHED ANNUALLY FROM 1967 TO 1973.

73. DEPARTMENT OF THE ENVIRONMENT
1968: A Study of Aggradation and Degradation of the South Saskatchewan River, Gardiner Dam, Saskatoon; Progress Report, 1964-1967 IHD Project Saskatchewan-1, 30 p., Prepared Jointly by Inland Waters Branch, Department of the Environment and Saskatchewan Water Resources Commission, Hydrology Division.

ABSTRACT:

This report provides a detailed summary of sediment survey work undertaken on the South Saskatchewan River downstream from Gardiner Dam during 1964-1967. This includes hydrometric, profile and sediment data.

NOTE: THIS REPORT WAS PUBLISHED ANNUALLY FROM 1968 TO 1975.

74. DEPARTMENT OF THE ENVIRONMENT
1971: Morphological Study of the Edwards Creek Watershed; Internal Report, Sediment Survey Section, Water Survey of Canada, Inland Waters Branch, Ottawa, 32 p.

ABSTRACT:

The morphology of the Edwards Creek watershed in Manitoba is evaluated in this report, emphasizing the settling basin, floodway and deltas which formed at the mouth of the floodway.

Hydrometric data consists of flow discharges from March to October, 1957 to 1969 recorded at the hydrometric station near Dauphin. A sediment sampling program was initiated in 1969 and suspended-sediment data collected at three sampling stations from March to October of that year. In addition, bed-material samples were obtained at selected sites on the drainage system of the watershed.

Volumetric data of sediment deposition and erosion in the settling basin, floodway and delta were obtained from topographic surveys conducted by the Prairie Farm Rehabilitation Administration in 1957, 1960, 1964 and 1968.

To evaluate long-term flow discharges and suspended-sediment yields, the data for the former were reconstructed for the period 1913 to 1956 and for the latter from 1913 to 1968 through correlation and regression analyses. A tentative value for long-term bed-load discharge was obtained through the evaluation of bed-material particle-size distributions, volumes of eroded or deposited sediments and differences in suspended-sediment discharges at the three sediment sampling stations.

Detailed descriptions of all computational methods and survey techniques are given in the Appendices of this report. Results and all pertinent data are illustrated by means of tables and graphs. Finally, results are evaluated and recommendations made for decreasing the sediment discharge for the upper and lower Edwards Creek watersheds, increasing the sediment trapping efficiency of the settling basin and stabilizing the floodway channel.

The report recommends a continuation of the suspended-sediment sampling program for several years, and the carrying out of topographical surveys of the settling basin, floodway and delta at periodic intervals.

75. DEWIS, F.J., LEVINSON, A.A. and BAYLISS, P.
1972: Hydrogeochemistry of the Surface Waters of the Mackenzie River Drainage Basin, Canada - IV Boron Salinity Clay Mineralogy relationships in modern deltas; Geochimica et Cosmochimica Acta, Vol. 36, No. 12, p. 1359-1375.

ABSTRACT:

Bulk sediment samples from two northern Alberta Freshwater Deltas and from the Marine Mackenzie River Delta were analyzed for mineralogy and the trace elements B, Cu, Zn, Ni, Li and Mn. In both the Marine and Freshwater Deltas the total clay content of the samples correlates highly with the trace elements studied. The concentration of B and total clay in the bottom sediments from all three deltas increases with distance from the mouth of each delta (the increase is less well-defined for Cu, Zn, Ni, Li and Mn). The trace element variations in the two freshwater deltas result from variations in total clay content. If the two similar freshwater deltas were preserved in an ancient environment, they could be mistaken for a marine delta based solely on the boron content of the whole rock analyses as the boron content ranges are analogous to those reported for modern and ancient marine deltas. The slopes of regression lines, computed between the boron and total clay content of the freshwater and marine delta sediments are equal, which indicates that boron absorption from sea water is not a significant factor in controlling the boron content of sediments in the marine Mackenzie River Delta. Although the separation of the marine and freshwater regression lines is statistically significant, discriminant function analysis shows that the mineralogical and chemical differences of the samples can be explained better by variations in the source area rather than by their occurrence in either the freshwater or marine deltas. The lower water temperature of the Mackenzie River Delta Environment, and low silica content of the Mackenzie River, may be factors in the small boron increase in the marine delta for an alternative absorption explanation. The boron content of shales and other fine-grained sediments may be useful to determine distance from a stand line, but its usefulness as an indicator of paleosalinity is questionable.

76. DOWDESWELL, J.A.
1982: Debris Transport Paths and Sediment Flux Through the Grinnell Ice Cap, Frobisher Bay, N.W.T. Canada; Unpublished M.A. Thesis, University of Colorado, Boulder, 176 p.

ABSTRACT:

Watts Glacier is suggested to be of subpolar thermal regime for two reasons: (1) The basal debris rich zone, assumed to be the result of bulk freezing-on, is approximately two orders of magnitude thicker than typical values for temperate glaciers. (2) Erratic pulses of basally derived sediment in melt streams draining Watts Glacier indicate a dynamic subglacial drainage network. The presence of a glacier snout largely frozen to the bed, with a zone of pressure melting up-glacier, is therefore inferred.

77. DREW, D.P.
1982: Piping in the Big Muddy Badlands, Southern Saskatchewan, Canada; In: Badland Geomorphology and Piping, R. Bryan and A. Yair, Editors, Geo Books, Norwich, p. 293-304.

ABSTRACT:

This paper provides a description of two surveyed pipes in the Big Muddy Badlands. A possible origin for these pipes as well as a possible sequence of development for the piping in this area are proposed.

78. DUNN, C.E.
1980: Lake Sediment and Water Geochemistry of the Carswell Structure, Northwestern Saskatchewan; Saskatchewan Mineral Resources, Report No. 224, 36 p.

ABSTRACT:

Sediments and waters from 70 lakes in the vicinity of the uranium-bearing Carswell structure were analyzed for a wide range of elements. The study provides base-line data, and includes a number of elements seldom considered in lake-sediment studies. In general, away from the known one-bodies element concentrations are of the same order as commonly found in lake sediments. Factor analysis of the data indicates a uranium-chloride-bicarbonate association in the waters. In the sediments the clay mineral fraction is the dominant factor controlling metal distributions. The ferro-manganese component plays a subordinate role and the organic fraction is important only in controlling Zn and Cd distributions.

Dispersion halos of many elements (notably U, Ni, Cu, Co, Be and Y) down-drainage from the ore-bodies situated near Cluff Lake are clearly depicted on contour maps. Five additional areas of weak uranium anomalies are in association with enrichments of several other elements.

79. DURETTE, Y.J.

1976: Data Report, Lake of the Prairies, 1973. Morphological Survey; Internal Report, Sediment Survey Section, Applied Hydrology Division, Water Resources Branch, Inland Waters Directorate, Environment Canada, 10 p.

ABSTRACT:

This report briefly describes the instrumentation and methods used in the data collection as well as in the data editing procedures. It presents a summary of the data available and examples of the type and form of this data. A quick evaluation of the 1973 survey data and of the topographic data available from the PFRA Engineering Service has prompted the Sediment Survey Section to produce only a "Data Report" at this time. The conclusions and recommendations of this report were therefore formed after evaluating data quantity and quality rather than analyzing data to determine sedimentation processes.

80. DURETTE, Y.J.

1981: A Capacity Study of Reid Lake; Internal Report, Sediment Survey Section, Water Resources Branch, Inland Waters Directorate, Environment Canada, Ottawa, 21 p.

ABSTRACT:

This report briefly describes the instrumentation and methods used in the data collection, reduction and analysis of the hydrographic survey of Reid Lake conducted in 1975 and 1976. It presents the results of the data analysis, a verification of these results using annual inflow rates of water and sediment, and a comparison of these results with the original capacities as derived from the 1941 survey. Finally, it presents a calculated sedimentation rate (38.8 dam^3), an estimated useful life expectancy of the reservoir (1300 years), and recommendations for further verification.

81. EGGINTON, P.

1976: Hydraulic, Morphologic and Morphometric Studies of Selected Rivers Along the Route of the Mackenzie Highway; Report of Activities, Part A, Geological Survey of Canada, Paper 76-1A, p. 229-231.

ABSTRACT:

In response to requests by the Mackenzie Highway Environmental Working Group for environmental studies along the Mackenzie Highway, a fluvial geomorphic study was initiated with two main objectives: 1) to study the hydraulic and morphologic behaviour of selected rivers over which the Mackenzie Highway crosses with a view to (a) assessing the accuracy of design estimates and (b) evaluating any modifications to the channel regime and form caused by construction; and 2) to initiate long-term studies into river processes and form.

82. ENVIRONMENT CANADA
1973: Effect of Laboratory Combination of Suspended Sediment Samples on Accuracy of Computation of Sediment Loads; Internal Report, Water Survey of Canada, Inland Waters Directorate, Western and Northern Region, 47 p.

ABSTRACT:

The purpose of the investigation was to determine if total concentration suspended sediment samples could be combined and analyzed as an integrated sample withina fixed criteria. A combination of samples would result in improved suspended sediment laboratory efficiency which must be weighed against decrease in accuracy of the computation of suspended sediment load in the stream. An analysis was carried out on three streams in Western Region of different sizes and regimes, with a total of approximately four station-years of record analyzed.

The average error introduced by combining samples was highly variant with a range of 0 to 15 percent on an annual basis, 0 to 60 percent on a monthly basis and 10-65 percent on a daily basis. Individual time period errors were significantly higher with the extreme deviations on a daily basis normally exceeding several hundred percent. The excessive error introduced by combination of total concentration samples is not balanced by large improvements in laboratory efficiency. The present practice of analyzing each suspended sample individually should be continued and the computations of suspended sediment load based on the results of the individual concentrations determined.

83. ENVIRONMENT CANADA
1976: Sediment Investigations and Network Planning in Manitoba; Report Prepared by Sediment Survey Section, Water Resources Branch, Department of Fisheries and the Environment, Ottawa, in Cooperation with the Winnipeg District Office of the Water Survey of Canada, and the Water Resources Division of the Department of Mines, Resources and Environmental Management, Province of Manitoba, 14 p. + Appendix.

ABSTRACT:

A sound knowledge of sediment transport and morphological processes in a watershed is essential in the planning and development of water use projects in that watershed, and an understanding of these processes depends in its turn upon the availability of an adequate body of observed sediment data.

Sedimentation and morphological problems in Manitoba are not at present serious, but with growth in population and economic expansion and the increased demands on the province's water resources attendant upon this growth, it can be expected that problems with sediment transport and morphological processes will cause increasing concern. (A description of these processes appears in this report.)

This study looks at the potential areas of concern in Manitoba, assesses these in terms of the type of investigation required, and assigns a recommended time frame to each. It is then a matter for the Government of Manitoba, using this project list as a guide, to determine its own priorities within the framework of cost-sharing arrangements with the Government of Canada.

The vehicle for the study is an existing cooperative data-collective arrangement between the Water Resources Branch of Fisheries and Environment Canada and the Manitoba Department of Mines, Resources and Environmental Management.

84. ENVIRONMENT CANADA

1978: Sediment Investigations and Network Planning in Alberta; Report Prepared Jointly by Sediment Survey Section, Water Resources Branch, Department of Fisheries and the Environment, Ottawa, in Cooperation with the Calgary District Office of the Water Survey of Canada, and the River Engineering Branch, Alberta Department of Environment, 15 p. + Appendices.

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A sound knowledge of sediment transport and geomorphological processes in a watershed is essential in the planning and development of water use projects in that watershed, and an understanding of these processes depends in its turn upon the availability of an adequate body of observed sediment data.

Sedimentation and geomorphological problems in Alberta are not at present serious, but with growth in population and economic expansion and the increased demands on the province's water resources attendant upon this growth, it can be expected that problems with sediment transport and geomorphological processes will cause increasing concern. (A description of these processes appears in this report.)

This study looks at the potential areas of concern in Alberta, assess these in terms of the type of investigation required, and assigns a recommended time frame to each. It is then a matter for the Government of Alberta, using this project list as a guide, to determine its own priorities within the framework of cost-sharing arrangements with the Government of Canada.

The vehicle for the study is an existing cooperative data-collection arrangement between the Water Resources Branch of Fisheries and Environment Canada and the Alberta Department of Environment.

85. ENVIRONMENT CANADA
1979: Distribution of Suspended Sediment Concentration at two Stream Stations in Manitoba; Internal Report, Sediment Survey Section, Water Resources Branch, Inland Waters Directorate, Ottawa, 62 p.

ABSTRACT:

Increasing costs of obtaining and analyzing suspended sediment samples have led to a reduced program in the number of total cross-sectional samplings and an increased reliance on data obtained from one vertical sampling by local observers or single point intake sampling by automatic samplers to compute suspended sediment yield. This project was initiated to study the cross-sectional variability of suspended sediment concentration and particle-size distribution in order to assist in the selection of sampling points or verticals and to assess the probable accuracy of the estimating methods.

The study was conducted using suspended sediment concentration and particle-size data, for the period 1962 to 1974, from the following two sediment sampling stations: Assiniboine River at Headingley (05MJ001) and Red River near Ste. Agathe (05OC012).

Further study on additional streams is planned and will be available in forthcoming publications.

86. ENVIRONMENT CANADA
1979: A Review of the Classification of Existing Monitoring Stations in Saskatchewan; Inland Waters Directorate, Water Survey of Canada, Western and Northern Region, Regina, 11 p.

ABSTRACT:

A review of the classification for all existing sediment stations as listed in Schedule A of the Canada-Saskatchewan Memorandum of Agreement for Water Quantity Surveys was completed. The classification was carried out according to the Inland Waters Directorate Directors Committee Policy Decision related to the Sediment Survey program and the Report of the Task Force on Sediment Surveys "IWD Sediment Quantity Surveys and Studies".

The results of the review indicates a shift towards the provincial end of the federal-provincial spectrum. For the full program sediment sites, 2 of the 6 indicated greater provincial support. Several reasons explain this occurrance. Schedule A was used as a reference datum to determine shifts in classification. It is realized that this would introduce bias because Schedule A was never intended to reflect the classification of sediment stations. Also, in the past WSC-Saskatchewan has never requested the recovery of the costs assessed to operating a sediment network which was heavily slanted towards a miscellaneous program as costs were minor. This action resulted in little concern by both the Province of Saskatchewan and Water Survey of Canada for responsibility classification of sediment stations.

During the review, the relevance and need for new sediment stations or relocation of sediment stations was not considered. It was felt that this would be a worthless task until such time as the report on "Sediment Investigations and Network Planning" is complete for Saskatchewan.

A spinoff from the review is the formation of a firm base of responsibility for the existing network and the establishment of guidelines for directing future sediment sampling programs.

87. ENVIRONMENT CANADA
1979: IWD Sediment Quantity Surveys and Studies; Report of the Task Force on Sediment Surveys, Inland Waters Directorate, 24 p. + Appendices.

ABSTRACT:

This report lists the Inland Waters Directorate Committee Policy decisions relating to the Water Resources Branch sediment survey Program. It also includes the rationale for sediment quantity surveys and studies and an analysis of the present sediment survey program and future recommendations made by the Task Force on Sediment surveys.

88. ENVIRONMENT CANADA
1979: Proposed Classification of Alberta Sediment Program Stations; Internal Report, Water Survey of Canada, Western and Northern Region, Inland Waters Directorate, Calgary, 19 p. + Appendix.

ABSTRACT:

This review of the Canada-Alberta Memorandum of Agreement, as it pertains to the classification of sediment stations, was carried out according to the directions received from the IWD Directors' Committee Policy Decision based on the report of the Task Force on Sediment Surveys, IWD Sediment Quantity, Surveys and Studies.

The review examines the federal responsibility for sediment stations are existing in the Memorandum of Agreement dated April 1, 1979 listed in the 1979/80 Schedule "A". Responsibility of IWD regarding the lead role, joint role with Alberta, or just a support role with Alberta, is discussed. Future federal responsibility is examined as previously reviewed in the Sediment Planning Report - Alberta published in 1978.

89. ENVIRONMENT CANADA

1980: Historical Sediment Data Summary Canadian Rivers to 1978; Biennial Publication, Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, 121 p.

ABSTRACT:

The first edition of a new publication series titled Historical Sediment Data Summary for Canadian Rivers was produced for data to 1974. This publication contains a summary of historical monthly and annual mean suspended sediment load, and annual extremes of daily suspended sediment concentration and loads and total annual suspended load. Commencing with the 1978 publication, data are presented entirely in the International System of Units (SI).

90. ENVIRONMENT CANADA

1980: Status Report on Sediment Station Classification; Internal Report, Water Survey of Canada, Western and Northern Region, Inland Waters Directorate, Winnipeg, 14 p. + Appendices.

ABSTRACT:

This report gives the current status of the sediment station classifications and compares them to those recommended by the WSC, WNR Regional Chiefs in May, 1979.

A review of sediment station classification was carried out by the Regional Chiefs in 1979 based on the IWD Director's Committee Policy Decisions and the report, "IWD Sediment Quantity Surveys and Studies", by the Task Force on Sediment Surveys. In these reviews it was found that there were 135 sediment stations in the WNR and that 24 stations did not have the desired responsibility classification.

As of 1980/81 there are 130 sediment stations and 15 of these stations do not have the desired responsibility classification.

It is anticipated that from 1981/82 forward there will be 129 sediment stations to operate and that there will be 2 stations which will not have the desired responsibility classification.

91. ENVIRONMENT CANADA

1982: Portage Reservoir Sedimentation Study, 1982; Report Prepared Jointly by Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Winnipeg and Manitoba Department of Natural Resources, Water Resources Branch, Water Control Works Section, Winnipeg, 19 p. + Tables and Figures.

ABSTRACT:

The Portage Reservoir with a capacity of 10,317 acre-feet at elevation 868 feet, a surface area of 1,540 acres and a length of 13 miles was formed by the construction and operation of a dam and control structure in the Assiniboine River. The dam and control structure as part of the Assiniboine River Diversion flood control project.

The rate of sedimentation in the reservoir was determined from topographic surveys and suspended sediment surveys to be less than one percent of the reservoir capacity per year.

It was found that the reservoir functions as a reservoir with deposition predominating in years with flood peaks of less than 40,000 cfs and as a river channel with erosion predominating in years with higher flood peaks.

It was postulated that the reservoir would fill with sediment until a river channel, adequate to convey the flows under the changed conditions, remained. The dimensions of the new channel and the time required to reach equilibrium were estimated. It was estimated that the reservoir formed by the new channel would have a volume below elevation 868 feet roughly equal to one-third of the original reservoir volume and that equilibrium would be achieved in about 86 years.

92. ENVIRONMENT CANADA
1984: Sediment Data Reference Index Canada 1982; Biennial Publication; Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, 47 p.

ABSTRACT:

The first edition of a Sediment Data Reference Index was published for data to 1972. It contains a tabulation of locations where sediment data in Canada were collected by the Water Survey of Canada. The index has been subdivided alphabetically by province or territory, with sediment survey stations listed alphabetically. Commencing with the 1978 publication, data are presented in the International System of Units (SI) and will continue to be published biennially.

93. ENVIRONMENT CANADA
1985: Sediment Data Canadian Rivers 1983; Annual Publication, Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, 233 p.

ABSTRACT:

This paper contains data on streamflow, daily suspended sediment discharges, daily mean suspended sediment concentration, particle-size distribution of suspended sediment, particle-size distribution of bedload, and water temperature for days sediment samples were collected for the Calendar year 1983.

NOTE: During the years 1948 to 1960, some sediment data were collected for several Prairie rivers to meet the needs of particular projects. The first Paper containing sediment data incorporates a selection of these data and also data for part of the year ending September 30, 1961 at stations established for the continuing program. The second issue is a biennial publication covering only the continuing program for the 1962 and 1963 water years. All subsequent editions titled Sediment Data Canadian Rivers were published annually. Commencing with the 1978 publication, data are presented entirely in the International System of Units (SI).

94. FAULKNER, P.H.
1970: Aspects of Channel and Basin Morphology in the Steveville Badlands, Alberta; Unpublished M.Sc. Thesis, Department of Geography, University of Alberta, Edmonton, 83 p.

ABSTRACT:

Extensive badlands have developed peripheral to the Red Deer River in southern Alberta. Exposed on the retreating valley walls, bentonic clays are being eroded by convectional storms in the spring and summer favouring the rapid development of gullies which extend from the river into the adjacent upper prairie.

Gully evolution in the Steveville vicinity can be illustrated sequentially by examining the hypsometric curves and stream profiles of the ten tributary gullies of increasing size. The series of stream profiles and basin forms represent a model illustrating changes that occur as the basins enlarge and extend laterally in the upper prairie where no headwater competition occurs. In order to assess whether the planimetric characteristics of the basins similarly change, the drainage systems can be ordered and consistency in the areal division of the networks examined from the relevant Hortonian regressions.

The characteristics of the ten channels as they emerge from their watersheds were mapped in the field, and cross-sections measured on each channel segment. The magnitude of bankfull discharge can be assessed and this value and other channel characteristics correlated with drainage net variables. Exponents of plotted regressions can be compared with those obtained in other areas, deviations being explicable within the presented model. The mode of gully extension in the Steveville area, and changes that take place in both hydraulic and morphometric relationships as this extension proceeds are theirs elucidated.

95. FROELICH, C.R.
1979: An Intensive Surface Water Quality Study of the Muskeg River Watershed, Volume II Hydrology, Report Prepared for Alberta Oil Sands Environmental Research Program, Project HY2.5, 194 p.

ABSTRACT:

Various hydrological features of the Muskeg River basin in northeastern Alberta have been characterized as part of a program intended to obtain an understanding of natural regimes and baseline processes in the Athabasca Oil Sands area. Physiography, meteorological characteristics, channel characteristics, streamflow, and suspended sediments of the Muskeg River watershed are described. Precipitation patterns were estimated on a summer-winter basis and described for the years 1974 through 1977. Estimates of potential evaporation and evapotranspiration model, indicate that evapotranspiration rates are limited by water supply rather than by energy input. Analysis of channel characteristics show that flows in the flat channels in the highlands spill over banks more frequently than other areas in Alberta. At some sections, such flooding occurs every year which has appeared to establish a slowly draining ecosystem adjacent to the channel. Channels that drain large bogs maintain more winter flow than others. Streamflow characteristics described included: (1) basin-wide flow measurements and their correlation, when possible, with continuous measurements at two sites; (2) spacial distribution of water yields for 1976 and 1977; (3) channel flow volumes for 1976 and 1977; (4) basin-wide high and low flows for 1976 and 1977; and (5) annual flow durations for two sites where continuous measurements were available. Suspended sediment characteristics for the two major sampling sites described include flow loading relationships, concentrations, and loading hydrographs for 1976 and 1977. Basin-wide estimates were made and it was concluded that concentrations are low compared to most data on other Alberta streams. The average suspended sediment yield (3200 tonnes per year) of the Muskeg basin was found to be very low compared to other basins in the oil sands area.

96. FUDGE, R.J.P. and BODALY, R.A.
1984: Postimpoundment Winter Sedimentation and Survival of Lake Whitefish (Coregonus clupeaformis) Eggs in Southern Indian Lake, Manitoba; Canadian Journal of Fisheries and Aquatic Sciences, Vol. 41, No. 4, p. 692-700.

ABSTRACT:

Flooding of Southern Indian Lake for hydroelectric power development has resulted in extensive wave erosion of glacio-lacustrine clay shore material and greatly increased suspended sediment levels. Winter sedimentation on spawning grounds of lake whitefish (Coregonus clupeaformis) ranged from 0.03 to 0.14 g dry wt sediment cm^{-2}. This deposited a layer 1-4 mm in depth. The sediment, low in organic content, was categorized as silty clay. The effect of this winter sedimentation on survival of whitefish eggs was tested at four sites over a range of winter sedimentation rates. Three of the sites were whitefish spawning areas. Egg survival was significantly higher for eggs incubated in cages designed to minimize exposure to sedimentation compared with survival in cages allowing full exposure to sedimentation. Winter

sedimentation rates and whitefish egg survival were negatively correlated for cages designed to minimize exposure to sedimentation, white egg survival in the exposed cages was uniformly low.

97. GALAY, V.J.
1967: Regime Characteristics of North Saskatchewan River Near Drayton Valley; Open File Report 1967-10, Highways Division, Research Council of Alberta, 18 p.

ABSTRACT:

This report consists principally of an assembly of data collected in the course of the field investigations, together with supporting data obtained from other sources. These data cover the geographic and hydrologic features of the river, the geometry and hydraulics of its channel, the granulometry of the channel materials and the nature of their movements, and the performance of various engineering structures and river training works.

98. GALAY, V.J.
1969: Observed Forms of Bed Roughness in an Unstable Gravel River; Proceedings of the Thirteenth Congress of the International Association for Hydraulic Research, 31 August-5 September, 1969, Japan, p. 85-94.

ABSTRACT:

Echo-sounder measurements on an unstable gravel river in Alberta, Canada, indicate that minor bed forms develop on the river bed during high flow conditions and high bed load transport. The wave length of these bed forms appears to decrease with an increase in flow intensity and depth, for relatively small values of depth to grain size.

Air photographs of this river reveal that the major bed forms (bars) are crescent-shaped with horns pointing downstream.

99. GALAY, V.J.
1971: Some Hydraulic Characteristic of Coarse-bed Rivers; Unpublished Ph.D. Thesis, Department of Civil Engineering, University of Alberta, Edmonton, 140 p. + Appendices.

ABSTRACT:

Data from the field and laboratory, dealing with the behaviour of coarse-bed rivers, are analyzed under the following topics: the sampling and analysis of coarse bed-material, the threshold of motion condition, the amount of material in transport, the resistance to flow, the design of stable channels, and the depth of scour at river bends.

The adequate sampling of a coarse river-bed should consist of a subsurface scoop sample, borings and a surface grid sample. Analysis of a wide range of field data indicated that the largest stones in a mixture start to move at lower velocities than the same size stones in a uniform bed of rip rap. The analysis of flume experiments using dimensional analysis resulted in the conclusion that the relation depth is a significant parameter in assessing the rate of bed-load transport. A comparison of the measured bed-load transport in the Elbow and North Saskatchewan Rivers to computed transport indicated that the existing formulas are inadequate. The measurement of the actual protrusion height of stones on a river-bed resulted in the development of a flow resistance equation, for rigid beds, which is somewhat dissimilar from the formulas of Keulegan and Kellerhals. Formulas relating stable channel width, depth, and slope to discharge and size of bed-material were developed for coarse-bed channels. The sounding of river bends before, during, and after floods revealed that scour holes at bends were relatively stable; filling of the scour hole during recession of the high flows did not take place. Analysis of a number of forced and free bends led to the development of tentative design formulas for assessing the maximum depth of scour. This maximum depth of scour was related to the width, radius and internal angle of the river bend.

The importance of more adequate field data was stressed and recommendations regarding field and laboratory investigations were formulated.

100. GALAY, V.J.
1983: Causes of River Bed Degradation; Water Resources Research, Vol. 19, No. 5, p. 1057-1090.

ABSTRACT:

River bed degradation can proceed downstream as well as upstream depending upon the cause of degradation. The causes of downstream progressing degradation are primarily related to changes in independent river channel variables, such as increase in water discharge, decrease in size of bed material, and decrease in bed material discharge. The causes of upstream progressing degradation are all related to an imposed increase in river slope which can occur as a result of natural river behaviour or by man-made changes. Study of various case histories indicates that river slopes are increased by lowering a base level, by decreasing the length of a river, or by removal of a control point. Case histories also show that downstream and upstream progressing degradation can act in combination along a river system: downstream progressing degradation along the main stream of a river system can initiate upstream progressing degradation on a tributary.

101. GALAY, V.J., PENTLAND, R.S. and HALLIDAY, R.A.
1982: Degradation of the South Saskatchewan River below Gardiner Dam; Proceedings of the Annual Conference of the Canadian Society of Civil Engineers, Vol. III, p. 955-981.

ABSTRACT:

The construction of Gardiner Dam on the South Saskatchewan River has resulted in trapping of substantial sediment loads within the reservoir causing some degradation of the river bed below the dam. Analysis of cross-section and sediment data collected since the closure of the dam indicates that the average bed level has dropped 2 metres (6.5 ft) downstream of the dam and that the bed has started to armour (become coarser). The median size of the bed material within the active flow channel has changed from 0.38 mm to about 4.0 mm. The degradation has progressed approximately 8 km (5 miles) below the dam. The pattern of the river channel has not altered significantly and the river has become more stable since the operation of the dam, especially in the lower reach just above Saskatoon.

Computations, using empirical relationships, show that ultimate degradation may be about 7.0 metres (23 ft) if further armouring of the bed takes place. More detailed computations using the U.S. Army Corps of Engineers HEC-6 sediment model indicate that, by the year 2001, total degradation may be about 5.3 metres (13.8 ft). The computer model also verifies that a high flood release could result in a substantial increase to the degradation that has already taken place.

102. GHEBRE-EGZIABHIER, K. and ST. ARNAUD, R.J.
1983: Carbonate Mineralogy of Lake Sediments and Surrounding Soils: 1. Blackstrap Lake; Canadian Journal of Soil Sciences, Vol. 63, No. 2, p. 245-257.

ABSTRACT:

The carbonate mineralogy of the Blackstrap Lake sediments in central Saskatchewan indicates that the lake deposits are composed of carbonatic minerals semilar to those found in surrounding soils and glacial deposits. Textural differences reflect the transport of finer materials (silts and clay) from the adjacent eroding landscapes. In particular the persistence of dolomite in the silt fractions of the lake sediment is a good indication that part of the calcite together with the dolomite are derived from surrounding soils. The sediment sand fraction contains appreciable Mg-bearing calcite and mollusk shells of pure calcite. Changes in the ionic concentrations of the lake water indicate that dissolution-precipitation processes have affected sediment composition. The increased calcium carbonate equivalent percentages and the presence of secondary magnesium-bearing calcites in the lake sediments suggest that this is so, particularly since erosional processes could not account entirely for the differences observed between the sediments and surrounding soils. The presence of gypsum and the nature of the secondary calcites in the Blackstrap Reservoir sediment tie in well with the known historical background of the Reservoir. The increased ionic concentration of the lake water over the last 15 yr or so since the original inception of the Reservoir is attributed to the influx of drainage waters, evaporation and possibly the effects of groundwater entry form below.

103. GILBERT, R.
1984: The Movement of Gravel by the Alga Fucus vesiculosus (L.) on an Arctic Intertidal Flat; Journal of Sedimentary Petrology, Vol. 54, No. 2, p. 463-468.

ABSTRACT:

Measurements of the weights of gravel clasts with attached flucoid algae Fucus vesiculosus from an arctic intertidal flat at Pangnirtung in northern Canada indicate that stones are floated when the algae is at least three times heavier than the clast. When the algae is not large enough to float the clast to which it is attached, the form drag and lift which it provides allow moderate tidal currents to move very much larger stones than would be possible otherwise. These mechanisms offer a means of transporting coarse sediments to deep water where they may augment or be confused with ice-rafted materials.

104. GILBERT, R. and CHURCH, M.
1980: Sedimentary Environments of Proglacial and Nonglacial Lakes on Cumberland Peninsula, Baffin Island; Report Submitted to the Geological Survey of Canada, 62 p.

ABSTRACT:

Preliminary studies on Cumberland Peninsula, Baffin Island of four lakes receiving significant quantities of sediment from Penny Icecap and nearby smaller glaciers, and of five similar lakes in the same area receiving no glacial sediment indicate the following:

1. Waters of all lakes have dissolved sediment loads of less than 10 mg/L with highest values in the glacial lakes where ion scavenging can occur from the fine suspended sediment.

2. Zooplankton are more abundant by approximately an order of magnitude in the nonglacial lakes and the carbon content of the sediments is similarly higher.

3. Sediments from the proximal glacial lakes consist of alternating light and dark laminae several millimetres thick which can be traced among cores taken throughout the lake. Although the lighter laminae contain less than 10% sand, grading and load structures indicate these beds are probably microturbidites associated with summer inflow events. However, no annual layers (varves) could be recognized, although estimated rates of sedimentation are only several millimetres per year, suggesting that underflow events occur infrequently during the summer. In one proximal glacial lake, much coarser sediment is probably associated with slumping, grain flows and turbidity currents from small, high energy streams entering around the sides of the lake.

4. Sediment in distal glacial lakes consists of poorly laminated very fine silts and clays, which have passed from the proximal lake in suspension.

5. The nonglacial lakes are dominated by organic and chemical processes of sedimentation. Three distinct sedimentary environments are postulated:

   a. a region near the mouths of inflowing streams where higher loads of clastic sediment are deposited as distinct laminae perhaps associated with nival and summer rain induced floods;

   b. a region of lower rates of sedimentation where prominant bands of iron rich sediment accumulate probably at locations where the redox boundary pauses a few centimetres below the surface as sediment is deposited;

   c. a region where rates of sedimentation may be too low for distinct iron bands to develop.

105. GILBERT, R. and CHURCH, M.
1983: Contemporary Sedimentary Environments on Baffin Island, N.W.T. Canada: Reconnaissance of Lakes on Cumberland Peninsula; Arctic and Alpine Research, Vol. 15, No. 3, p. 321-332.

ABSTRACT:

Studies were made of four lakes receiving significant quantities of glacial sediment, and of five lakes receiving no glacial sediment. All waters contain less than 10 mg L^{-1} dissolved sediment, with highest values in the glacial lakes where ion scavenging can occur from fine suspended sediment. Zooplankton abundance and total carbon content of sediments are an order of magnitude higher in the nonglacial lakes.

Shallow box cores were taken in order to study the recent sediments. Two depositional environments can be recognized, one dominated by physical processes with higher rates of clastic sedimentation, and one dominated by chemical processes, especially iron/manganese concentration. In the former, which occurs in both glacial and nonglacial lakes, periodic high sediment inflow associated with glacial or nival melt, or with summer precipitation, produces distinct laminae. Although they contain less than 10% sand, grading and load structures indicate that these beds were probably deposited from underflows or interflows in the lake. Iron bands containing up to 39% by weight iron form where sedimentation occurs slowly and continuously under redox conditions which change as deposition occurs. Despite a very pronounced difference between winter and summer inflow to the lakes, varves could not be recognized in any of the sediments.

106. GILBERT, R. and SHAW, J.
1981: Sedimentation in Proglacial Sunwapta Lake, Alberta; Canadian Journal of Earth Sciences, Vol. 18, p. 81-93.

ABSTRACT:

The hydrologic and limnologic conditions of Sunwapta Lake, a small proglacial lake in the Canadian Rocky Mountains, were investigated with special reference to the sedimentology of this lake. Discharge and suspended sediment concentrations of the inflowing streams were measured to give estimates of sediment input. Distribution of large loads of fine glacial sediment is largely by an inflow- and wind-controlled circulation, which commonly fluctuates diurnally. The spatial distribution of sedimentation was determined by use of sediment-collecting pans placed on the lake bed. Turbidity currents are rare with only one event monitored in 2 years. This event was caused by a burst of highly sediment-charged inflow water. The rarity of turbidity currents is attributed to the high sediment concentration in the lake water, which results from the small size of the lake in relation to the inflow. Wind-generated water movement at the lake floor ranges from 0.0-0.03 m/s while the maximum recorded velocity of the turbidity currents was 0.32 m/s.

Sedimentation rates are calculated and six cores from the lake bed, each containing sediment deposited over several years, are described. Although bedding and lamination are found in all cores, correlation between cores was not possible. Sedimentary characteristics are related to inflow and lake conditions: laminated and massive beds of medium to fine sand and silt are related to turbidity events, graded laminae in coarse and fine silt to diurnal variations in lake currents, and massive beds in silt to periods of continuous sedimentation without diurnal variation. Deformed beds result from subaqueous slumps.

107. GILBERT, R., SYVITSKI, J.P.M. and TAYLOR, R.B.
1985: Reconnaissance Study of Proglacial Stewart Lakes, Baffin Island, District of Franklin; Current Research, Part A, Geological Survey of Canada, Paper 85-1A, p. 505-510.

ABSTRACT:

Stewart Lakes are dammed by neoglacial moraines in a through-valley between Gibbs and Sam Ford fiords in northeastern Baffin Island. Maximum water depth on the basis of spot soundings is 108 m. Glaciers are retreating at rates between 19 and 34 m/a, and the lake level has lowered from 69 m above sea level to 55 m as a result of ice retreat and downcutting of the moraines. On 13 September 1983, suspended sediment concentrations in Stewart Lakes varied from 66 to 109 mg/L. In Refuge Harbour (Gibbs Fiord) the concentration in overflowing fresh water was 135 mg/L. These values are significantly higher than those measured in most other ice-proximal lakes and fiords.

108. GILL, D.A.
1971: Vegetation and Environment in the Mackenzie River Delta, Northwest Territories: A Study in a Subarctic Ecology; Unpublished Ph.D. Thesis, Department of Geography, University of British Columbia, 694 p.

ABSTRACT:

The intent of this study is to describe and analyze the interrelations of vegetation and environment in the east-central settor of the Mackenzie River Delta, Northwest Territories. It traces the sequence and function of the allogenic events which create varying habitat systems and determines whether environmental modification, once initiated on terra nova is directional - is either a physical or floristic expressions.

In determining the sequence and influence of physical environmental factors, the following parameters were measured, employing standard instruments and field investigation techniques: micro-relied; depth, areal extent, and duration of flooding; thickness, areal extent, and particle-size distribution of annual deposits of alluvium; magnitude and significance of erosion; patterns of microclimatic variation (including air temperature and humidity, evaporativity, precipitation, wind speed, solar radiation, and net radiation); lake and channel temperatures, soil pH, moisture (hygrotope class), and temperature; development of varying active layer depths; and freezeback of the active layer.

To analyze the vegetation of the study area, the phyto-sociologic methods of the Braun-Blanquet (Zürich-Montpellier) school were applied. Nine seral associations and the climax ecosystem were studied; each was fitted into a successional category. Plant succession was analyzed by reconstructing the course of vegetative development from pioneer to climax community with the aid of successional transects.

Results of this study indicate that environmental and floristic changes in the Mackenzie Delta are directional that given the formation of new ground, such as on the slip-off slope of a shifting channel, ecologic variation will follow a predictable direction. As the serol sequence advances, autogenic influences become dominant over the allogenic initiatoxs until in the climax association, relatively steady-state conditions of environment and vegetation are attained.

109. GILL, D.
1972: Modification of Levee Morphology by Erosion in the Mackenzie River Delta, Northwest Territories, Canada; In Geomorphology, R.J. Price and D.E. Sugden, Compilers, Institute of British Geographers, Special Publication, No. 4, p. 123-138.

ABSTRACT:

While the unequal deposition of sediments controls the gross morphology of deltas, erosional processes also affect the distribution of sediments. In addition to normal fluvial erosion,

levee morphology in an Arctic delta may be significantly modified by wave action, ice abrasion, slumping and solifluction, and thermal degradation of perennially frozen sediment. This paper analyses the action of these processes and shows how they affect levee retreat and rates of aggradation and progradation of slip-off slopes and point bars along shifting channels in the Mackenzie River delta.

110. GILL, D.
1972: The Point Bar Environment in the Mackenzie River Delta; Canadian Journal of Earth Science, Vol. 9, No. 10, p. 1382-1393.

ABSTRACT:

Helicoidal flow and sediment sorting along the convex portion of shifting channels in the Mackenzie River Delta cause point bars to be composed of the coarsest material available to plant colonization. Sorting by acolian action further reduces the fine fraction in point bar soils. Coarse-textured deposits maintain a lower water content and a higher soil temperature than other deltaic surfaces, thus nearly every point bar is colonized by a discrete plant association. This ecosystem is dominated by balsam poplar (Populus balsamifera), and the distribution of well developed poplar stands is restricted to point bars. The successional ecology of this ecosystem is discussed in relation to the point bear environment.

111. GRAHAM, D.R.
1973: Section I - 1971 Sediment Survey for the Peace-Athabasca Delta Region; Report for the Peace-Athabasca Delta Project Group, Edmonton, Alberta, 28 p. + Appendix.

ABSTRACT:

This report, Section I, discusses the 1971 sediment survey for the Peace-Athabasca Delta Region. The sediment program for the Peace-Athabasca Delta project consisted of sampling at seventeen different river locations and on five lakes. Preliminary examination of suspended sediment results indicates very little correlation with flow. The report presents a description of sediment samplers used, sediment sampling techniques and sediment station analysis. Suspended sediment analysis results are presented in the Appendix.

112. GRIFFITH, W.H. and WALTON, B.D.
1978: The Effects of Sedimentation on the Aquatic Biota; Prepared for the Alberta Oil Sands Environmental Research Program by Renewable Resources Consulting Services Ltd. AOSERP Report 35, 86 p.

ABSTRACT:

A review of the effects of sedimentation on aquatic biota is presented. The detrimental effects of increased suspended and settled sediments on fish, bottom invertebrates, and primary productivity are documented. It is shown that the upper tolerance level for suspended sediment is between 80-100 mg/l for fish, and as low as 10-15 mg/l for bottom invertebrates. Recovery of the aquatic biota from increased sedimentation is dependent on the severity of sediment additions and the discharge level of the rivers or streams. Recovery from short-term additions of sediment is usually complete within one year.

The use of remote sensing and biomonitoring to locate sources of sedimentation is discussed. Remote sensing can generally be used to identify point sources of sedimentation, define flow patterns, choose sampling stations, interpret ground survey data, and maintain permanent records of changes in water quality. Biomonitoring can be used to monitor water quality, especially with regard to sedimentation, since alterations in the environment are reflected by the indigenous biota.

The sedimentation characteristics in the Alberta Oil Sands Environmental Research Program (AOSERP) study area are presented and observations are made on the potential for erosion and sediment production. The AOSERP study area is divided into twelve hydrological zones and each zone is classified for erosion potential. The zones having a high erosion potential are: (1) lower Ells basin and eastern slopes of Birch Mountains (Zone 1); (2) tributaries immediately north of Fort McMurray (Zone 6); (3) Christina River basin (Zone 7); (4) Hangingstone and Horse River basins (Zone 8); (5) MacKay River basin (Zone 9); (6) Dunkirk River basin (Zone 10); and (7) upper Ells River basin (Zone 11).

Road construction, pipeline construction, general construction (urban and industrial sites), vegetation removal, overburden removal, and pit excavation, tailing ponds, settling ponds, and diversion channels were identified as possible sources of unnatural increases in suspended and settled sediments in the AOSERP study area. The effect of development activities on the hydrological regime and the aquatic biota is shown. The scale of the disturbance and the length of the recovery period are also predicted. Development activities such as road building and pipeline construction will affect a number of the watershed basins; therefore, they were classified as having regional effect and were considered to be of greatest concern.

113. GUTHRIE, J.E. and ACRES, O.E.
1979: Organic Coolant in Winnipeg Riverbed Sediments; Atomic Energy of Canada Limited, Paper AECL-6317, 29 p.

ABSTRACT:

Between January and May, 1977, a prolonged leak of organic collant occurred from the Whiteshell Nuclear research Establishment's nuclear reactor, and a minimum of 1450 kg of coolant entered the Winnipeg River and was deposited on the riverbed. The level of radioactivity associated with this coolant was low, contributing less than 0.2 µGy (0.02 mrad) a year to the natural background gamma radiation field from the riverbed.

The shape of the deposition zone was similar to that previously established for the process water plume from the outfall, i.e., parallel to, and near the east bank of the river. An estimated 900 kg of coolant was deposited non-uniformly over 21 ha (0.21 km^2) of the riverbed, extending about 1 km downstream from the outfall. Small amounts of coolant were later found in sediment samples taken near the west bank of the river at Lac du Bonnet. This indicates that some coolant had diffused across the river, possibly an effect of the abnormally low flow of the Winnipeg River during January to August, 1977.

Although coolant was found on the riverbed, the concentration of coolant in the water samples never exceeded 0.02 mg/L, the lower limit of detection. The mortality of crayfish, held in cages where the riverbed was covered with the largest deposits of coolant, was not significantly different from that in the control cages upstream of the outfall. No evidence of fish kill was found.

114. HAMMER, K.M. and SMITH, N.D.
1983: Sediment production and transport in a proglacial stream: Hilda Glacier, Alberta, Canada; Boreas, Vol. 12, p. 91-106.

ABSTRACT:

Hilda Glacier, a small cirque glacier in the Canadian Rocky Mountains, yields two principal types of sediment: ablation till, deficient in fine material and produced by rockfalls and avalanches falling on to the glacier surface, and basal lodgement till, rich in fines and formed mainly by subglacial erosion. Recent recession from its Neoglacial maximum has exposed large areas of basal till with thin veneers of ablation till which, when combined with present subglacial and supraglacial debris, provide abundant material for erosion and transport by the meltwater stream. Sediment transport measurements over two summers (1977-1978) showed that bedload and suspended load occur in approximately equal proportions and that dissolved loads are minor. Local source variations, especially bank slumps, are a major cause of scatter in sediment rating curves. Suspended-sediment concentrations are greater early in the melt season due to availability of loose sediment produced by freezing and thawing. Other contributors to scatter in suspended-sediment rating curves include rain showers and diurnal hysteretic effects. Although the distinction between bedload and suspended load is never sharp, available data suggest that the sand/gravel grain-size boundary (-1ϕ) approximates the

suspended load/bedload division for characteristic Hilda flows transporting, and spatial distributions of till types, leads to the following computations of fluvial sediment sources; for suspended load - 6% supraglacial, 47% subglacial, 47% channel banks; for bedload - 46% supraglacial, 27% each subglacial and channel banks. Supraglacial debris provides only about one-fourth of all fluvial sediment, but nearly half of the bedload.

115. HANSON, D.G. and DRENNAN, L.
1980: Portage Reservoir Sedimentation Study, 1971; Internal Report, Water Survey of Canada, Inland Waters Directorate, Environment Canada, Winnipeg, 10 p. + Tables and Figures.

ABSTRACT:

This report describes the 1971 sediment survey of the Assiniboine River Reservoir near Portage la Prairie. This survey was the first in a series of proposed surveys to determine the rate of capacity loss due to sedimentation in the reservoir. This study was also essential in providing geomorphic data for the effective operation of the reservoir and its associated diversion channel.

During the survey, thirty sediment ranges were established and profiled. Suspended sediment samples were collected from selected ranges and bed material samples were collected from all ranges. The survey results are illustrated by tables and graphs.

116. HARDY ASSOCIATES (1978) LTD.
1982: Alluvial Sedimentation of the Mackenzie River System; Report Prepare for B.C. Hydro and Power Authority, 73 p. + Appendices (2 Volumes).

ABSTRACT:

This report provides the results of a study of the alluvial sedimentation patterns and related vegetation succession along the Liard-Mackenzie River System and at selected study areas in the delta.

117. HARPER, J.R. and PENLAND, S.
1982: Beaufort Sea Sediment Dynamics; Final Report to the Geological Survey of Canada, October, 1982, 40 p.

ABSTRACT:

Numerous scientific studies have been conducted in the Beaufort Sea since the original Beaufort Sea Project of 1974 and 1975, but, to date, these studies have not been synthesized with respect to sediment dispersal. This report provides a state-of-the-art interpretation of information related to sediment dynamics and outlines a revised sediment dispersal model for the Beaufort Sea.

Analysis of the sediment budget indicates that the Mackenzie River is the major contributor of sediment to the southern Beaufort Sea system, contributing over 95 percent of the total. Analysis of mud volumes and sedimentation rates on the shelf indicates that the major portion of the sediment contributed by the Mackenzie River is deposited in shallow water near the delta. This observation is supported by analysis of suspended sediment concentrations (SSC), which were derived from LANDSAT imagery enhancement. The processed images often shown very high SSC values (>100 mg/L) inside the 10-m contour and low SSC values (<10 mg/L) seaward of the 10-m contour with a strong SSC gradient in the 5-m to 10-m water depths. These analyses indicate that the proximal delta area serves as the primary sediment sink for river sediment. The enhanced LANDSAT imagery also shows that the turbid water of the Mackenzie River plume is frequently deflected to the north and east from the delta and serves as a sediment source to these areas of the shelf, although sedimentation rates (<0.2 mm/yr) are nearly one order of magnitude less than those near the delta (>2 mm/yr).

Wave climate data and current meter data were analyzed for potential transport frequency and potential transport directions. The results show that the shelf seaward of the 20-m contour is dormant in terms of transport potential except on the western shelf where slightly stronger currents occur. Landward of the 20-m contour sediments can be transported by combined wave and current action; transport is most active inside the 5-m contour where waves may suspend material over 50 percent of the time. On the central and eastern part of the shelf net transport is directed to the northeast; longshore transport at the coast is controlled by the dominant northwest storm wave approach and is directed to the east or south, depending on shoreline orientation. Shelf transport on the western shelf may be directed to either the northwest or southeast.

Geologically recent changes in sea level and supply patterns have affected shelf sediment dispersal. Areas of the shelf with little or no ongoing sedimentation (the eastern-most and western-most parts of the shelf) have coarse surficial sediments, which are thought to be relict and deposited under different hydrodynamic conditions than exist at present. As such, the shelf morphology and sediment character is a product of both present and past (early to mid-Holocene) sedimentary process.

118. HECKY, R.E.
1975: Southern Indian Lake: Sedimentary Environments, Recent Basin History and Implications of Inundation and Diversion; Fisheries and Limnology, Technical Report, Appendix 5, Vol. 1-D: Lake Winnipeg, Churchill and Nelson Rivers Study Board, Winnipeg, p. 1-60.

ABSTRACT:

Numerous sediment collections were made in southern Indian Lake in 1972 in connection with other tasks. The information gathered from these collections is summarized in this section in an attempt to determine present sedimentation patterns in the lake. Sediment cores from three stations allow the recent history of the lake to be elucidated. Knowledge of the present and past patterns of sedimentation is used in an attempt to forecast the eventual fates of sediments which will become available from shoreline erosion after inundation and diversion. The probable impact of turbidity and sedimentation of the different shoreline types classified and provisionally mapped by the physical impact study is evaluated, and the probable impact on specific regions is predicted based on the dominant shoreline type in any region and knowledge of present sedimentation in that region.

119. HECKY, R.E. and McCULLOUGH, G.K.
1984: Effect of Impoundment and Diversion on the Sediment Budget and Nearshore Sedimentation of Southern Indian Lake; Canadian Journal of Fisheries and Aquatic Sciences, Vol. 41, No. 4, p. 567-578.

ABSTRACT:

Shoreline erosion added an annual average of 4×10^6 t of mineral sediment per year to Southern Indian Lake (postimpoundment area, 2391 km^2) during the first 3 yr of impoundment. This erosion increased sedimentary input to the lake by a factor of 20. The lake retained 90% of this eroded material within its basin, and 80-90% of the retained material was deposited nearshore. Despite the production of extremely fine constituent particle sizes, eroding shorelines generated predominantly large day aggregates, initially transported offshore as bedload. During bedload transport, abrasion of clay aggregates producted fine particles that became suspended. Over 80% of the suspended load is lost to outflows from the lake because the suspended load is primarily fine silt and clay-sized particles, most of which do not settle even under winter ice cover. The extensive nearshore clay aggregate deposits are temporary, and net deposition in these areas will change to net erosion when input of sediment from eroding shorelines ceases. The effects of shoreline erosion on the lake's sediment regime will persist for decades.

120. HEIN, F.J.
1984: Deep-sea and Fluvial Braided Channel Conglomerates: A Comparison of Two Case Studies; In: Sedimentology of Gravels and Conglomerates, E.H. Koster and R.J. Steel, Editors, Canadian Society of Petroleum Geologists, Memoir 10, p. 33-49.

ABSTRACT:

Detailed comparisons of modern gravelly fluvial deposits from rivers in the Canadian Rocky Mountains and Cambro-Ordovician deep-sea valley-fill conglomerates (Cap Enragé Formation, Québec) reveal some similarities and differences.

Braided channel deposits in both deep-sea and fluvial settings occur in laterally fining/thinning units within concave-up lenses bounded by major scour surfaces at the base. Vertical sequences are mainly fining-upward, less commonly coarsening, 5-10 m thick for deep-sea and 2-3 m thick for fluvial channel fills. Main channel deposits in both settings are dominantly structureless.

Braid bar deposits in deep-sea and fluvial sediments occur in laterally coarsening/thickening units with flat bases and convex-up top surfaces. Vertical sequences vary depending upon locations within the bar complex and the type of braid bar. Generally, vertical sequences are fining-upward, 1-2 m thick, horizontally stratified or cross-bedded units. Planar tabular cross-stratification and irregular inclined cross-stratification are very common in deep-sea bar deposits. These features were not recognized in the fluvial conglomerates. Horizontal stratification consists of layers with different clast sizes or layers with alternating matrix-filled and open-work texture in fluvial conglomerates. Horizontal stratification consists of layers with different clast sizes or layers with alternating clast-supported and clast-dispersed texture in deep-sea conglomerates. Open-work texture was not observed in the deep-sea conglomerates.

Grading types and gravel fabric patterns are perhaps the most useful criteria in the distinction of fluvial from deep-sea conglomerates. Fluvial conglomerates are mainly upgraded, with less common normal or inversely-graded beds. Deep-sea conglomerates are mainly normally graded, with less common upgraded conglomerates and rare inversely or complexly graded beds. Deep-sea channel conglomerates have a-axis flow-parallel, a-axis upstream imbricate fabrics. In fluvial channels the smaller clasts may also assume an a-axis flow-parallel, a-axis imbricate upstream pattern. However, the coarser clasts are generally aligned in fluvial channels with a-axis flow-transverse, b-axis imbricate upstream. Braid bar deposits are distinguished on the basis of imbrication; in fluvial deposits imbrications are b-axis upstream; in deep-sea deposits imbrications are either a-axis upstream or a-axis upstream and downstream (bimodal). A-axis orientations in bedding are quite variable in both fluvial and deep-sea bar deposits and are not very reliable.

121. HODGES, W.K. and BRYAN, R.B.
1982: The Influence of Material Behaviour on Runoff Initiation in the Dinosaur Badlands, Canada; In: Badland Geomorphology and Piping, R. Bryan and A. Yair, Editors, Geo Books, Norwich, p. 13-46.

ABSTRACT:

This paper shows that the behaviour of different lithologic units under natural and simulated rainfall has a more complex response pattern than is usually assumed for semi- and badlands. Runoff development in the Dinosaur badlands has been compared with partial area and variable source area models but with recognition of lithology as the dominant factor controlling contributing areas.

More precisely runoff is controlled by the behaviour of surface materials and can expand or contract much more swiftly than envisaged in the standard variable source area model. Existing runoff models do not appear to be well-adapted to the complex, heterogenous lithology of the Dinosaur badlands. During most rainstorms runoff comes almost entirely from sandstones and silts, but in extreme events, which appear to be of greater geomorphic significance, the varied response of shale units becomes critical.

122. HODGSON, C.W.
1983: Biogeochemistry of Stream Waters: A Comparison of the Effects of Suspended Sediments and River-bed Biofilms; Ecological Bulletin (Stockholm), Vol. 35, p. 85-97.

ABSTRACT:

Stream water biogeochemistry is a complex interplay of a number of processes of conversion and transport. Gross parameters of mass transport, heterotrophic potential and depletion factors for in-stream organic substances are useful in an overall sense, but detailed knowledge of the mechanisms of some of the major processes is required. Thus, in the case of microbial uptake and mineralization, it is important to know the relative importance of the effects of sedimentary and river-bed biofilms. An expression is developed that describes the relative activities of the suspended sediments with that of the river-bed biofilms in overall stream biogeochemical processes. That expression takes the general form of an activity ratio, R sub a, for the effect of suspended sediments compared with river-bed biofilm: R sub a = constant . (whf) divided by (ud) where w is the sediment loading; h, the stream depth; f, the thickness of the diffusion layer; u, the stream velocity; and d, the average particle diameter.

123. HOLLINGSHEAD, A.B.
1968: Measurements of the Bed-load Discharge of the Elbow River; Inpublished Ph.D. Thesis, University of Alberta, Edmonton, 95 p. + Appendices.

ABSTRACT:

Estimates of the bed-load discharge of a gravel bed river were made by the following four methods:

1. direct measurements using two types of portable bed-load samplers;
2. the injection of tracer bed material and the sampling of tracer concentrations within the bed-load;
3. direct measurements of the refilling rate of a large pit excavated in the river bed;
4. the application of several bed-load discharge formulae, using measured hydraulic parameters.

Field observations were carried out during the summer of 1967 on a short reach of the Elbow River near Bragg Creek, Alberta. Surveys of the channel geometry and longitudinal bed and water surface profiles were carried out. The bed material was sampled using various methods. The velocity distribution was measured as three cross sections at several stages of flow, and hydrophone observations were used to determine the start of bed movement. A number of bed-load discharge samples were obtained and a short period of tracer injection was accomplished.

The basket and VUV type samplers gave reasonable estimates of the bed-load discharge; however, a large number of samples, requiring improved handling equipment would be advantageous. The use of tracers gave the highest estimates of bed-load discharge however the period of injection was insufficient to satisfy the assumptions on which the method was based. Estimates based on the pit excavation and refilling rate are limited because of the unfortunate timing of the field work. This pit was partially excavated prior to a large flood which occurred on May 30, 1967. The application of the sediment transport formulae gave a wide range of estimates of bed-load discharge for all stages of flow. The applicability of each formula to the range of hydraulic and sediment parameters is discussed. An assessment of hydraulic conditions corresponding to the first displacement of bed material from field observations is most useful for checking and altering the formulae used.

A continuation of the bed-load discharge sampling program is recommended with the use of a more efficient winch system. A study of the total sediment transport and channel processes along the Elbow River, including sediment accumulation in the Glenmore Reservoir, is suggsted.

124. HOLLINGSHEAD, A.B.
1968: Sediment Transport Measurements, Elbow River at Bragg Creek, 1968; Internal Report, Alberta Research Council, 23 p.

ABSTRACT:

This report presents the data collected during the summer of 1968 and an analysis of the data collected to date, under the cooperative program on sediment transport measurement.

125. HOLLINGSHEAD, A.B.
1969: Sedimentation Study, Glenmore Reservoir; Limited Distribution Report by Highway Research Division, Research Council of Alberta, 23 p.

ABSTRACT:

This report contains the data collected during the 1968 summer field surveys, a brief analysis of the information collected to date and a few recommendations for future reservoir sedimentation studies.

126. HOLLINGSHEAD, A.B.
1971: Sediment Transport Measurements in Gravel River; Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 97, No. HY11, p. 1817-1834.

ABSTRACT:

A limited number of suspended sediment and bed-load sampling measurements have been presented for a fairly steep foothills river in southwestern Alberta. Bed-load and total sediment transport rating curves are presented. The bed is at a state of incipient movement at a flow of about 800 cfs, which is exceeded about 30 days per yr on the average. An estimate of the average total sediment yield at this site is 190 tons per sq. mile annually.

Popular transport formulas give a wide range of estimates for bed-load discharge, if they are applied in a rigid manner with only channel geometry and bed-material sizes specified. The use of measured mean velocity rather than slope provides a more realistic assessment of total flow resistance. These formulas can be adjusted to give more reasonable estimates if the stage corresponding to the start of movement is observed in the field.

A proposed method of estimating bed-material transport rates, based on hydrophone observations coupled with velocity measurements in the field, and on a graphical correlation of flume data, has been used successfully. Because of its inherent check on incipient conditions, such a method is considered better for gravel-bed rivers than the conventional transport formulas.

A number of further field studies in various types of streams will be required to check the reliability of this method.

127. HOLLINGSHEAD, G.W. and RUNDQUIST, L.A.
1977: Morphology of Mackenzie Delta Channels; Proceedings of the Third National Hydrotechnical Conference, Canadian Society of Civil Engineers, Quebec City, May 30-31, 1977, p. 309-326.

ABSTRACT:

The Mackenzie Delta distributes peak flows of about 28,000 m^3/s (1,000,000 cfs) through a maze of distributary channels which range in width from two metres to several thousand metres. The delta channels are ice-covered for several months of the year, but following breakup, water temperatures rise sharply for a brief period. Flow velocities are comparatively low. Breakup is mild although accompnied by extensive flooding in the outer Delta to a depth of 1.2 m (4 ft).

The Delta sediments are predominantly silt and fine sand with minor amounts of clay, organics and gravel. Permafrost impinges more closely on the channels than previously suspended and is considered an important factor in controlling the unusual shape of delta channels. Steep underwater side slopes and submerged benches are common elements of the channel bed topography. Permafrost is aggrading beneath some benches. Wave action and thermal niching of ice-rich banks are considered the primary factors contributing to observed rapid channel shifting.

Permafrost has been located at shallow depths beneath the bed of Shallow Bay. The permafrost is degrading on the western side of the Bay where the shoreline has retreated 0.68 km during the past 45 years. Its effect has been to overconsolidate the sediments which contributes to steep underwater slopes. This phenomenon will minimize the volume of dredged excavations in the delta channels.

128. HOLLINGSHEAD, A.B., YAREMKO, E.K. and NEILL, C.R.
1973: Sedimentation in Glenmore Reservoir, Calgary, Alberta; Canadian Geotechnical Journal, Vol. 10, p. 109-119.

ABSTRACT:

Glenmore Dam on the Elbow River in the City of Calgary was constructed in 1932 in connection with Calgary's water supply. Various surveys have been conducted over the years to record the progress of sedimentation in the 23 000 acre-foot (28.4 x 10^6 m^3) reservoir. It is estimated that in the 36 year period to 1968, nearly 10% of the original full-supply capacity was lost due to silting. The average composition of deposits is estimated as 35% sand, 50% silt and 15% clay sizes.

The quantity of accumulated deposits checks reasonably with estimates of sediment load in the Elbow River, which rises in the eastern slopes of the Rocky Mountains approximately 65 miles (105 km) southwest of Calgary. An apparent average sediment yield of approximately 240 tons per square mile per year (84 tonnes/km^2/year) from this 470-square-mile (1217 km^2) basin is compared with yield data from other points in Western Canada and the northwestern United States.

129. HUDSON, H.R.
1982: Aspects of the Suspended Sediment Regime of an Intermediate Size Eastern Slopes Drainage Basin; Proceedings of the Canadian Hydrology Symposium on the Hydrological Processes of Forested Areas, 14-15 June, Fredericton, New Brunswick, p. 499-520.

ABSTRACT:

Eight years of detailed suspended sediment sampling of the Elbow River at the Bragg gauge, and detailed observations of river bank erosion processes for two of these years at 20 sites along the river, with concurrent detailed sampling of the main stem and tributaries from the headwaters downstream, were used to describe the suspended sediment regime of the 793 km^2 Elbow River basin above Bragg gauge.

The Elbow River annual hydrograph is characterized by low winter flow with a few minor early spring peaks leading to a major spring flood peak. Several smaller rainfall and/or snowmelt peaks can occur during the recession period. In summer, frontal storms can produce floods in excess of the spring peak flood while local convectional storms produce minor increases in the river discharge.

On the rising limb of the annual spring flood there is a strong relationship between discharge and suspended sediment concentration. Following the peak discharge, a rapid drop in sediment concentration occurs, with a marked shift in the suspended sediment rating curve. These features are explainable in terms of the hydrologic response and sediment supply constraints of the system.

The major sediment source in the mountains is surface wash of barren colluvium tributary slopes. Limited valley wall erosion also occurs, producing higher suspended sediment yields from some tributaries. In the foothills channel erosion provides almost all of the suspended sediment load. A conceptual bank erosion model is described which explains the high sediment concentration on the rising flood and the rapid drop in concentration following peak discharge.

130. HUDSON, H.R.
1983: Hydrology and Sediment Transport in the Elbow River Basin, S.W. Alberta; Unpublished Ph.D. Thesis, Department of Geography, University of Alberta, Edmonton, Alberta, 322 p.

ABSTRACT:

The 1210 km^2 Elbow River basin which drains the mountains, foothills and plains of the Eastern Slopes of the Rocky Mountains, was studied to investigate the hypothesis that runoff and sediment are derived unevenly in time and space from complex, intermediate sized, drainage basins. A network of 18 primary measurement stations was operated for two years to supplement available hydrologic and sediment yield data. Long term rates of suspended sediment, bedload and solute load transport were estimated from measured discharge - load relationships. Sediment sources and controlling processes were identified based on aerial photographs and field measurements.

The sediment yield regime of the Elbow River basin is controlled by the hydrologic regime and the sediment supply regime. The steep, gravel bed river has a typical high latitude runoff regime. Flows are low during winter when the river is frozen over. Winter snow fall is effectively redistributed so that it is largely removed over a short period to produce a spring snow melt flood which may be enhanced by rainfall. About 60% of the total annual discharge occurs during the three month snow melt period. Summer rainfall may generate several, generally smaller, flood peaks following the main spring flood. Small magnitude floods tend to be generated from snow melt in the mountains and upper foothills. Rainfall may complicate the response. Large floods are produced as the result of a combination of rainfall and/or snow melt from the whole of the basin.

Reservoir surveys show that the average suspended sediment output of the Elbow River system, since dam construction in 1932, is about 75600 t/yr, or 62.5 t/km^2/yr. The mountain suspended sediment yields, which average 2100 t/yr, or 11 t/km^2/yr, are derived largely from surface wash of barren, calcareous colluvium, within tributary basins. Yield is limited by sediment supply. Weathering of the calcareous bedrock produces little fine material and the finer textured valley wall morainic deposits are usually protected by forest or lag deposits at their toe. The majority of the annual transport occurs in spring when the ephemeral tributaries flow and when mass movements into the stream channel tend to occur. The upper foothills sub-basin yield of 3950 t/yr, or 16 t/km^2/yr, is derived almost equally from tributary and river channel and valley wall erosion. The lower foothills sub-basin yield of 12150 t/yr, or 34 t/km^2/yr, is derived almost exclusively from along the river channel. Upland erosion of the potentially highly erodible foothills is limited by vegetation protection and/or sediment trapping in tributary log jams and beaver dams. Bank and riparian erosion is also the primary source of the 58400 t/yr, or 138 t/km^2/yr, derived from the lower basin. Upland erosion of the potentially highly erodible glaciolacustrine and till surficial materials of the plains may occur as the result of rare runoff events.

On the rising limb of the annual spring flood there is a strong relationship between discharge and suspended sediment concentration. Following the peak discharge, a rapid drop in sediment concentration occurs, with a marked shift in the suspended sediment rating curve. About 55 to 75% of the total annual suspended sediment load is transported in ten days and 98% is transported during the high flow period (May, June and July). These features are explained in a conceptual bank and valley wall erosion model.

Bedload has been measured at several sites in the Elbow River basin using large basket and Helley - Smith bedload samplers. Significant time and spatial variations in the measured rates of bedload transport are attributed to sediment supply constraints, the mechanics of bed material motion and a downstream decrease in competence. Criteria for evaluating bedload formulae are proposed and several formulae are tested against measured loads at four sites on the Elbow River. Some frequently used formulae were totally unsuitable, whereas other could be modified to adequately describe the sustainable capacity bedload. Calibrated formulae were used to estimate the sustainable bedload capacity (i.e. the amount of bedload transport which would occur if there were no sediment supply - constraints) for the four main hydrometric stations on the river. The average mean capacity load increases downstream from the mountains through the foothills, but decreases through the plains (mountains 783 t/yr, upper foothills 2335 t/yr, mid foothills 13453 t/yr, lower basin 1013 t/yr). The average annual load, which reflects supply constraints, is approximately one quarter of the mean capacity load. The downstream discontinuity in bedload transport is accommodated by storage as sediment waves in the generally degrading channel.

In the mountains surface wash processes and throughflow readily dissolve the predominantly calcareous bedrock and regolith. The foothills are a groundwater recharge area. Rapid throughflow and saturated overland flow may inhinit solution of calcareous and sedimentary rock and regolith. In the plains the solute load is derived primarily from transient, regional groundwater flow influxes into the river valley, with very limited tributary and local groundwater inputs. Solute yields average 98 $t/km^2/yr$ in the mountains, 65 $t/km^2/yr$ in the upper foothills, 54 $t/km^2/yr$ in the lower foothills, and 25 $t/km^2/yr$ in the plains.

131. HUDSON, H.R.
1983: Evaluation of Selected Bed-load Formulae in a Steep Gravel Bed River; Proceedings of the 6th Canadian Hydrotechnical Conference, June 2-3, 1983, Ottawa, Vol. 1, p. 331-356.

ABSTRACT:

Guidelines for the selection and application of appropriate sediment transport formulae are not available for gravel bed rivers. Criteria for evaluating and modifying bed-load formulae are proposed and several formulae are tested against the revised bed-load data from the Elbow River at Bragg gauge, and from three other sites on the Elbow River, where bed-load had recently been measured with a Helley-Smith bed-load sampler. Some frequently used formulae are totally unsuitable, whereas others can be modified to adequately describe the mean capacity bed-load. However, no formula can describe the mean capacity bed-load at all points in the system.

132. HUNT, P.R.
1978: Transverse Bars and Bed Forms of the William River, Northwestern Saskatchewan; Unpublished M.Sc. Thesis, Department of Geography, University of Calgary, Calgary, 171 p.

ABSTRACT:

Braiding in the William River is accomplished by the deposition of medium grained sand in the form of transverse bars formed during low and medium flow discharges. Local variations in flow forming diverging and converging flow patterns were associated with the secondary circulation within sluiceway channels between bars and bed irregularities which contribute to the random distribution and changing bar morphology.

Under conditions of relatively stable low discharge, bars may grow to over 100 meters in length and/or width. In some cases bars migrate up to 15 meters per day, with the most rapid migration occurring at high mean flow velocities (i.e., in the order of 50 cm/second). Kinematic behaviour of such bars is caused by reduced stream power and sediment transport at bar crests and also by the growth and decay of bar patterns.

The hydraulics of transverse bars, expressed as depth-velocity-size plots indicate that stability fields of small and large scale bed forms overlap. Bed forms could not be classified on the basis of hydraulics or grain size.

Data on grain size reflect the well sorted source sediments of the fluvial channel sands. Small changes in texture are present where changes in stream power and bed configuration occur. However, finer sediments are deposited at most bar crests and coarser sediments within sluiceway channels between bars.

Ripple morphologies from the William River agree favourably with experimental flume results. Dune observations show greater variability and less agreement with empirical findings from the literature. The nearly identical hydraulics of ripples, dunes and transverse bars suggest that the superimposition of bed forms observed in the William River is not a time lag adjustment.

A comparison of depth-velocity data from the transverse bars in the William River with similar data from sand waves from other studies suggest that the two bed forms are somewhat similar. The similarity in depth-velocity hydraulics and length-height ratios, but differences in morphologies suggest that they may be related to river stage and subsequent flow patterns. Sand waves may be associated with deeper flows and parallel flow lines in planform. Transverse bars appear to correspond to shallow flows and diverging-converging flow patterns.

The hydraulics of transverse bars, expressed as depth-velocity-size plots indicate that stability fields of small and large scale bed forms overlap. Bed forms could not be classified on the basis of hydraulics or grain size.

133. INTERNATIONAL ROSEAU RIVER ENGINEERING BOARD
1975: Joint Studies for Coordinated Water Use and Control in the Roseau River Basin; Report to the International Joint Commission, September 1975. Appendix B, 87 p.

ABSTRACT:

Basin description, water resources and climatic information for the Roseau River Basin, are presented in this Appendix.

The climate in the basin is typically continental with pronounced maximum summer and minimum winter precipitation. The Roseau River and its tributaries generally attain their annual peak flows during April and May from snow melt augmented by rainfall. The perennial flooding and poor land drainage along certain reaches of the Roseau River, from the City of Roseau (Minnesota) to Stuartburn (Manitoba) and in the vicinity of Dominion City, have not only hampered the domestic pupulus, but also farmsteads and agricultural activities. Flood protective measures have been and continue to be implemented in both Canada and the United States. Upstream channel enlargement and drainage works in Minnesota, the Gardenton Floodway and land drainage works in Manitoba have had hydrologic effects on downstream areas in Canada.

The water quality of the Roseau River (in Canada) and its Canadian tributaries is acceptable for most water users. Parameters which may at times be unacceptable are colour, iron, nutrients and dissolved oxygen. In regard to sediment transport, the Roseau River is a low producing stream. Groundwater is the principal source of water for domestic and agricultural use in the basin and within the Canadian portion of the basin it is of acceptable quality, with the exception of the bedrock aquifers in the vicinity of Dominion City. Further surface water and groundwater quality data are required to adequately quantify the existing water quality within the Roseau River Basin.

134. J.D. MOLLARD and ASSOCIATES LIMITED
1984: Bank Erosion and Slumping Re-evaluation, Lake Diefenbaker, 1984; Report Prepared for the Shoreland Management Section, Land Protection Branch, Saskatchewan Environment, 26 p.

ABSTRACT:

Purposes of the office airphoto study were to assess Lake Diefenbaker shoreland from the standpoints of erosion and slumping, suggest horizontal setbacks for buildings, and identify problem areas. Over a 9-year period erosion rates of 1-1/2 to 3 m a year (75 measurements) and 3 to 5 m a year (65 measurements) are a common occurrence on promontories and some cliffed backshores. Bluff erosion exceeded 5 m a year at only a few locations (15 measured), with maximum rate of erosion being 13 m a year. About 100 measurements indicated erosion rates of 1-1/2 m or less. Most of the latter are located on the east side of Lake Diefenbaker south of Gardiner Dam, and in the upper end of the lake west of

South Saskatchewan Landing Bridge. All measured points are shown on photomosaics. The roughly 500-km long shoreline was also separated into segments having recommended horizontal setbacks, for purposes of permanent building structures, of 75, 100, 150, 200, 300 and 350 metres. Active sediment accumulation is taking place in coves and bays adjoining eroding headlands. At low reservoir levels, eroded till and shale surfaces are typically covered by a scatter of pebbles and boulders with little finer sediment.

135. JASPER, J.N.
1973: Suspended Sediment and Dissolved Material Transport in "Twisty Creek". A Small Subarctic Watershed; Hydrologic Aspects of Northern Pipeline Development. Environmental-Social Committee, Northern Pipelines, Task Force on Northern Oil Development, Report No. 73-3, p. 645-664.

ABSTRACT:

Data are presented for suspended sediment and dissolved material transport in a small subarctic watershed. Variation of sediment concentrations and yield with discharge is analyzed and total sediment loss from the watershed estimated. Temporal and spatial variation in water chemistry is examined in an attempt to determine source area for runoff. Estimates of basin hydrologic characteristics are obtained utilizing hydrochemistry data.

136. JASPER, J.N.
1976: A Mackenzie Valley Watershed for Assessment of Hydrologic Design at Stream Crossings; 1975-1976 Report for the Hydraulic Design Assessment Committee, Environmental Working Group, Mackenzie Highway, 38 p. + 3 Appendices.

ABSTRACT:

Streamflow and precipitation data were collected during 1975 in 21 small drainage basins along the route of the Mackenzie Highway. Analyses of study results suggest that, despite above average snow accumulation in several areas since 1972, the melt period weather conditions have not produced extreme flood peaks. Consequently most of the data plotted within a narrow band on diagrams relating peak flow and drainage areas to predicted 50 year design flows. Several cases of floods close to or exceeding the design flows have been observed, however, suggesting that estimates of design flows by highway consultants may be less conservative than previously assumed.

Culvert performance at a number of stream crossings have been examined and generally found to fall below fish passage requirements. The main conditions responsible for their poor performance include high velocities resulting from culvert icing or even blockage, and the formation of plunge pools and outlet waterfalls when the culvert invert is installed above the stream channel bed. Observation of flow velocities, icings, and bed mobility at future bridge or culvert sites suggest that similar conditions will occur in other areas, unless effective remedial measures are developed and implemented.

137. JASPER, J.N.
1976: Hydrology and Sediment Movement Patterns of a Subarctic Upland Watersheds; Unpublished M.A. Thesis, Department of Geography, Carleton University, Ottawa, 187 p.

ABSTRACT:

The magnitude and temporal characteristics of rainfall, runoff, and the components of total erosion for a subarctic upland watershed were monitored during July and August, 1972-75. Although accuracy of the estimate is somewhat uncertain due to bedload sampling difficulties, calculated total sediment yield during the study period was determined to be about 980 tonnes/km^2/field season. The data also suggest that bedload forms the greater portion (approximately half) of total sediment yield from the watershed. Yield of suspended sediment was generally lower, except for the 1973 field season, while loss of material in solution was relatively insignificant.

The long term representativeness of the study period is difficult to assess due to the short duration of runoff and sediment data, and the general inability to compare and extrapolate regional hydroclimatic records to the study area. Despite this, the range of environmental conditions during the three field seasons was great and probably envelop the long term summer average. Erosion values for Twisty Creek are in the upper part of the range for other mountainous regions, but are lower than expected for the amount of runoff. This supports the hypothesis that both relative and absolute amounts of the components of total erosion are limited by availability of erodable material.

138. JOHNSTON, W.A.
1922: Sedimentation in Lake Louise, Alberta, Canada; American Journal of Science, Vol. 4, p. 376-386.

ABSTRACT:

This paper discusses the formation of annual sediment layers in Lake Louise bottom sediments. Summer deposition is characterized by coarse material while winter deposits consisted of silts and clays. This was due to a change in turbidity from summer to winter. The winter ice cover curtails wind assisted turbidity thus permitting the deposition of the previously circulating smaller particles. A comparison with Ottawa Valley sediment cores shows that the annual layers in Lake Louise bottom sediments are much thinner. This is probably due to Victoria Glacier being only slightly active.

139. JOSEPH, H.C.

1982: A Study of Heavy Metal Transport in Irrigation Return Flows of Southern Alberta; Unpublished M.Sc. Thesis, Department of Geography, Queen's University, Kingston, 211 p.

ABSTRACT:

With the identification of agriculture as a major contributor of pollutants to receiving waters, knowledge has gained rapidly on the quantity and quality of many contaminants. Heavy metals in agricultural drainage waters are perhaps least understood. Of particular relevance is the identification of chemical forms of heavy metals that are biologically available. Examination of irrigation return flows in semi-arid southern Alberta provided an opportunity to investigate heavy metal fluxes and chemical transport mechanisms in a unique agricultural setting. The characterization of the pollutant contributions from other agricultural areas can perhaps be approximated from this area. Seven irrigation return flows and one distribution canal were sampled for unfiltered and filtered waters, as well as suspended solids material (using a continuous-flow centrifuge on-site). Samples were collected during June, July, August and September. All water and sediment samples were analyzed by Atomic Absorption Spectrophotometry for total (HNO_3-HCl digestion) concentrations of Cu, Mn, Zn, Fe, Co, Ni, Cr, Cd and Pb. Selected suspended solids samples were further analyzed using partial chemical extractions of 0.5 M $MgCl_2$, 2.5% HCl and 10% HCl. Statistical and graphical analysis of heavy metal concentrations of all samples, demonstrated minimal fluctuation throughout the season, and little variation between sampling sites. A consistent ordering of metal concentrations was noted: Fe greater than Mn greater than Zn, greater than Cu for all samples. Partial chemical analyses demonstrated a very small percentage of suspended solids-associated metals to be readily available for aquatic biota. Large quantities of all heavy metals are associated with the residual fraction. Thus heavy metal contributions to receiving waters of the Bow and Oldman Rivers are primarily non-available to biota and are at levels very similar to surrounding agricultural soils.

140. KANG, S.-D.

1982: Sediment Transport in a Small Glacial Stream: Hilda Creek, Alberta; Unpublished M.Sc. Thesis, Department of Geology, University of Illinois at Chicago Circle, Chicago, 267 p.

ABSTRACT:

Detailed measurements of sediment transport were carried out through summer 1979 in the small outwash stream of Hilda Glacier, Banff National Park, Alberta. An important aspect of this work was the construction of a wooden dam, with a 6' by 2' spillway through which all water and sediment passed, for accurate bed-load measurements. Total sediment load was sampled with an elongated box pushed into the spillway overflow to collect both water and sediment in transport. Full-width bed-load was sampled separately by tilting an elongated basket into the overflow at short time intervals.

Different empirical relationships between sediment transport and water discharge for bed-load and suspended load were tested. No other models were found to be significantly better than the commonly accepted power relationship.

Gravel often moves in quasi-periodic pulses with periods of about 14 minutes that appear to be independent of water and sediment discharge. Low correlations between bed-load and water discharge are due to quasi-periodic and random movements of bed material as well as variations in source supply. Total bed-load can be calculated rather accurately from relatively long periods of short-term measurements.

Transport rate of each whole-phi size of sediment load was correlated with water discharge. A sharp change of R-square occurs at about -1ϕ (2 mm). Sizes finer than 0ϕ (gravel) are independent of discharge individually but correlate water water discharge when all gravel size fractions are treated as a group. With increasing water discharge, coarse components assume increasingly larger proportions of total load. Below 10 cfs, clay and silt dominate the load, whereas gravel dominates above 10 cfs.

Changing source supplies is one of the main factors which caused variation of both bed-load and suspended load. Rate change of water discharge causes significant variation in suspended concentration. Dissolved concentration is independent of water discharge in this setting.

141. KELLERHALS, R.
1972: River Regime Studies in Western Alberta; In: Mountain Geomorphology, O. Slaymaker and H.J. McPherson, Editors, Tantalus Press, Vancouver, p. 229-233.

ABSTRACT:

This report contains brief outlines of the major projects undertaken to date with reference to resulting reports and publications.

142. KELLERHALS, R.
1982: Effect of River Regulation on Channel Stability; In: Gravel-bed rivers, R.D. Hey, J.C. Bathurst and C.R. Thorne, Editors, Chichester, Wiley, p. 685-715.

ABSTRACT:

Regulation generally implies decreased flood peaks and often also decreased sediment supply from upstream. Bedload transport in gravel-bed channels tends to be characterized by a fairly distinct threshold, below which the bed is not active and the gravel transport rate is governed mainly by upstream supply. Consequently, regulation can drastically reduce, or even eliminate, a river's ability to move its bed materials. This explains why significant channel degradation downstream of major storage dams has not been observed in the case of gravel-bed channels. Tributaries with significant gravel bedloads do, however, create problems, because the regulated main-stem is often unable to remove the inflowing gravel from the confluence area. The potential for massive, long term aggradation exists at several confluence sites in Canada, although the effects are only just beginning to show up clearly. Recent data from the Peace River-Pine River confluence in northern British Columbia illustrate this problem.

Regulation often initiates a gradual reduction in channel size and capacity. The rate at which this progresses depends on the rate of sediment supply to the regulated reach, but the sequence of events is quite general; gravel bars become treed and flood-plain surfaces and side channels are blocked by debris jams, eventually to be filled with fines. Three Canadian rivers, the Peace, Bridge and North Saskatchewan, illustrate how the process varies somewhat, depending on sediment supply and on the pre-regulation channel morphology.

In Canada, regulation generally also implies much increased winter flows. There is some evidence that this can increase the severity of spring break-up ice jams, leading to the flooding of some terrace levels that would otherwise have been well beyond the reach of the river.

Two planned projects in northern British Columbia involve the regulation of highly braided and unstable outwash streams. These rivers are expected to be transformed into single-thread channels, or at least to a stable system of a few well defined channels.

The converse of regulation, unregulated diversion, is generally only practised on a small scale, but there are a few major unregulated diversions in Canada. The effects of unregulated diversions are exceedingly varied as they depend primarily on the details of the geological setting and substrate of the receiving channel.

143. KELLERHALS, R., ABRAHAMS, A.D. and VON GAZA, H.
1974: Possibilities for Using Suspended Sediment Rating Curves in the Canadian Sediment Survey Program; Consulting Report to Sediment Survey Section, Water Survey of Canada, Water Resources Branch, Inland Waters Directorate, Environment Canada, University of Alberta, Department of Civil Engineering, 86 p. + 4 Appendices.

ABSTRACT:

Sediment rating equations for predicting daily mean suspended sediment concentration and load from the corresponding water discharge have been developed for five river sites in Alberta and in western Saskatchewan for which four to nine years of daily suspended sediment data are available. The technique used to fit rating equations to the data is stepwise multiple linear regression which is applied to log-transformed data. At most sites only mean daily discharge (Q) makes a significant contribution towards explaining mean daily concentration (C), and the contributions of discharge-related variables, such as "rate of change of discharge" or "time from spring rise" are generally negligible. The residuals of the regression are serially correlated to such a degree that the significance tests normally applied to regressions are meaningless. Plots of the residuals show that the rating equations give poor predictions of C, both during the spring rise in Q and whenever major rain storms occur on the plains portion of the river basins. A preliminary attempt to improve prediction during major rain storms by including regionally averaged precipitation into the rating equations was unsuccessful. By themselves, rating equations or curves do not give a satisfactory representation of suspended sediment data, because they fail to represent properly the expected distribution of C. Rating equations based on log-transformed daily data also tend to underestimate long-term sediment yields. Monthly and yearly rating curves can, however, be used for this purpose. A considerable number of other studies concerning rating curves are reviewed and the findings of the present study are shown to be in general agreement.

The objectives of the Sediment Survey program are stated in a form which differs somewhat from the official published version, but which is essentially equivalent. The degree to which the present survey program meets these objectives is then discussed and some suggestions are made on how a survey program based on the extensive use of rating equations could permit a closer approach to the objectives.

144. KELLERHALS, R. and BRAY, D.I.
1971: Sampling Procedures for Coarse Fluvial Sediments; Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 97, No. HY8, p. 1165-1180.

ABSTRACT:

Procedures for sampling the bed material of gravel-bed rivers consist of five independent steps; selection of site and time, collection of a sample, determination of grain size, computation of size distribution, and presentation of results. Because several choices of methods are available at each step, much confusion exists in the literature. Simple geometric arguments, illustrated with a model based on densely packed cubes, are used to develop weighting factors to convert from one sampling procedure to another. Comparison with several sets of field data shows that the conversion method is applicable to gravel deposits. Differences remaining after conversion are attributable to random differences between samples, or to population differences. The grid-by-number procedure is the only surface-oriented procedure directly comparable (equivalent) to customary bulk sieve analysis. It is therefore the only correct sampling procedure for the study of surface-dependent phenomena. Additional field data are presented to compare three equivalent procedures.

145. KELLERHALS, R. and CHURCH, M.
1980: Comment on "Effects of Channel Enlargement by River Ice Processes on Bankfull Discharge in Alberta, Canada" by D.G. Smith; Water Resources Research, Vol. 16, No. 6, p. 1131-1134.

146. KELLERHALS, R., CHURCH, M. and BRAY, D.I.
1976: Classification and Analysis of River Processes; Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 102, No. HY7, p. 813-829.

ABSTRACT:

Aerial photographs and brief field visits are frequently the only data sources for the preliminary design of river engineering works in romote or undeveloped areas. Even if short-term field data are available, they may be misleading because of the nonuniform rates at which river processes take place. The major active processes are, however, reflected in the river morphology so that correct classification and interpretation of channel, flood-plain and terrace features on maps and photographs can, to some degree, overcome a lack of long-term data. Rivers present a wide spectrum of intermediate forms between the familiar classic braided and meandering types. This reflects a similarly wide spectrum of flow distribution, bed material size, sediment transport, and channel stability. Existing river classification schemes are reviewed and a modified system is proposed to take account of the gradual transition between classical types.

147. KELLERHALS, R., CHURCH, M. and DAVIES, L.B.
1979: Morphological Effects of Interbasin River Diversions; Canadian Journal of Civil Engineering, Vol. 6, No. 1, p. 18-31.

ABSTRACT:

Data on the morphological effects of 11 Canadian interbasin river diversions are presented and some of the more fully documented cases are discussed and illustrated. A classification of diversion routes is suggested and procedures for evaluting the morphological effects in each classification are proposed.

148. KELLERHALS, R. and GILL, D.
1973: Observed and Potential Downstream Effects of Large Storage Projects in Northern Canada; Proceedings of the 11th Congress of the International Commission on Large Dams, Madrid, Spain, p. 731-754.

ABSTRACT:

The recent start of regulation of the Peace River at the W.A.C. Bennett Dam in British Columbia, Canada, has initiated numerous environmental changes downstream. Indirectly it has also lead to extensive studies of the problems caused by regulating northern rivers. An attempt is made here to review these and other studies and to focus attention on the wide variety of downstream effects that should, in future, be considered.

The hydrologic regime of northern rivers is characterized by a snow-fed flood peak in spring or early summer and by minimum flows in late winter. The ratios between maximum and minimum flows depend on the amount of natural storage in a basin and vary from over 100 to less than 5.

Sedimentation problems caused by storage dams on northern rivers are poorly documented but indications are that they differ from problems encountered in arid or southern settings. Degradation-resistant gravel beds are common and sediment loads are generally low. The possible problem areas are tributary junctions, where aggradation of the main (regulated) river is likely, due to reduced carrying capacity. Initially, the tributary can degrade severely if, under natural conditions, the floods of the tributary had coincided with the floods in the main river.

Ice effects are also poorly documented. Delays in break-up could initiate a number of deleterious effects.

Active flood plains and deltaic wet-lands represent islands of high biological productivity in vast areas of less productive boreal forest. Many species of watefowl and aquatic mammals depend on these islands of habitat for survival. Flow regulation can cause a reduction in the size and quality of these biologically significant areas.

A large segment of the population of inland Northern Canada lives in close proximity to rivers and deltas and depends on fishing, trapping, and hunting to supplement a relatively meager subsistence, one which can be readily jeopardized by altering an appropriate hydrological regime. Hopes for improving the economic base of many northern settlements centre largely depends on developing their water-based recreational potential and to a lesser degree on forestry and commercial fisheries, all of which depend on suitable hydrologic conditions.

149. KELLERHALS, R., NEILL, C.R. and BRAY, D.I.
1972: Hydraulic and Geomorphic Characteristics of Rivers in Alberta; Research Council of Alberta, River Engineering and Surface Hydrology Report, No. 72-1, 53 p.

ABSTRACT:

This report presents tabular, graphical and photographic information on the hydraulic and geomorphic characteristics of Alberta streams, mainly as they appear in the vicinity of 108 gauging stations in the province. The data contained in the report represent a condensation of material assembled over a period of approximately ten years by various agencies.

150. **KING, C.R.**
1982: Factors Affecting the Planform of the Sturgeon River; Unpublished M.Sc. Thesis, Department of Geography, University of Alberta, Edmonton, 365 p.

ABSTRACT:

This study investigates the channel pattern of the Sturgeon River and the factors which affect it. Six short reaches were selected for study. Along these, data as to channel perimeter sediment, channel cross-section, valley and channel slope, and valley bottom width were collected. The factors which might account for the downstream change in channel pattern along each reach are discussed. Simple and multiple regression analyses are used to describe the relationships between the collected data and the planform variables: wavelength, radius of curvature, amplitude and sinuosity. The Sturgeon River data relations are compared to those given in the literature. Overall, slope and channel width are significant in determining the planform along these reaches. The channel perimeter sediment and the valley bottom width are important in places.

151. **KLASSEN, R.A.**
1975: Geochemistry of Lakes and Lake Sediments in the Kaminak Lake area, District of Keewatin, N.W.T.; Unpublished M.Sc. Thesis, Department of Geological Sciences, Queen's University, Kingston, 209 p.

ABSTRACT:

Factors affecting trace metal movement and fixation within lake sediments and the use of lake sediments in geochemical exploration for base metal mineralization on the Canadian Shield have been investigated in a region that is characterized by an arctic climate, tundra vegetation, continuous permafrost and post-glacial marine submergence. The area is near Kaminak Lake 150 km west-southwest of Rankin Inlet and lies within the Rankin Inlet-Ennadai greenstone belt of the Churchill structural province.

Six lakes of different mineralization, lithologic and overburden associations were studied. Lake sediments, overburden and rock samples were collected from each lake basin and analyzed for Cu, Zn, Mn, Fe, Co, Pb and Ni.

Lake waters were well circulated and the surface waters were near-neutral pH (7.0 to 7.6), saturated in dissolved oxygen (9 to 11 ppm) and had high electrical conductivities (160 to 360 µmho/cm). Schematic diagrams of the variations with depth of the parameters within all lakes are shown and discussed.

Lake sediments are quartz-feldspar rich silts with low contents of organic matter ($x \approx 6$, range 4 to 25 wt.) and clay minerals. Mangenese and iron oxides occur as surface flocs and as well developed chemically banded zones at and below the sediment surface and iron oxides occur as zones at the sediment surface.

Base metal element contents of the -210μ fraction of lake sediments are low and the levels are controlled by the amount of organic matter, and of manganese and iron oxides as shown by linear relationships with these parameters. There is also strong correlation among Cu, Zn, and Ni contents. Physical and chemical environments in the lakes affect the relative levels of organic matter and of manganese and iron oxides within the lake sediments and hence the relative levels of trace elements within and among lake basins. The trace metal content is higher within the lake sediments than within the surrounding surficial deposits.

Base metal sulphide mineralization did not detectably affect the lake water chemistries and neither it nor bedrock lithology were found to influence either the overall contents or dispersion patterns of trace elements within lake sediments. Ratios of Zn with organic matter and with Mn did not discriminate the influence of mineralization. Zinc contents of lake sediments were adequately explained by linear regression equations that incorporated either organic matter, manganese and nickel or organic matter, manganese and iron.

The use of lake sediments in geochemical exploration in this and similar areas of the Canadian Shield does not appear to be practicable.

152. KNOWLES, R. and WISHART, C.
1977: Nitrogen Fixation in Arctic Marine Sediments: Effect of Oil and Hydrocarbon Fractions; Environmental Pollution, Vol. 13, No. 2, p. 133-149.

ABSTRACT:

Nitrogen fixation (acetylene reduction) was measured in grab and core samples of sediments from the Beaufort Sea and Eskimo Lakes, Northwest Territories, Canada. Very low rates (about 25 mg N per sq.m. per year) were detected in untreated sediments. Activity was markedly stimulated by the addition of glucose, sucrose, lactose, mannitol and malate but much less so by acetate; negligible activity was supported by N-acetylglucosamine. There was no consistent effect of the presence or absence of oxygen. Nitrogen fixation potentials in glucose supplemented sediment samples showed large variation between stations, between samples from the same station and between depths within single cores down to 18 cm. Weathered Norman Wells crude oil, hexane, decane, dodecane and hexadecane had no effect, stimulatory or inhibitory, on nitrogen fixation or carbon dioxide evolution. 1, 2, 4-trimethulbenzene caused complete inhibition of nitrogen fixation but only partial inhibition of CO_2 evolution. There was no evidence of utilisation of any of the hydrocarbons tested during periods of over 30 days under the experimental conditions employed.

153. KRISHNAPPAN, B.G.

1980: Field Verification of an Unsteady Non-uniform Sediment Laden Flow Model; International Association for Hydraulic Research, Nineteenth Congress, New Delhi, p. 217-229.

ABSTRACT:

An application of a numerical model to the degradation problem in South Saskatchewan River below Gardiner Dam in Canada is presented in this paper. The model is capable of predicting the unsteady, non-uniform flows carrying sediment in streams with irregular cross sections. Some of the salient features of the model and the data requirement to run it are outlined. The model predictions are compared with the measured data for changes in both water levels and bed levels and a reasonable agreement is obtained.

154. KUIPER, E.

1962: Sedimentation South Saskatchewan Reservoir; Internal Report, Prairie Farm Rehabilitation Administration, 45 p.

ABSTRACT:

This report shows the possible effects of the proposed South Saskatchewan reservoir on stream bed aggradation and delta formation.

155. KUSHNIR, D.W.

1972: Sediments in the South Basin of Lake Winnipeg; Unpublished M.Sc. Thesis, University of Manitoba, Winnipeg, 92 p.

ABSTRACT:

Approximately 60 bottom sediment 'grab' samples were obtained in the south basin of Lake Winnipeg in the autumn of 1969 and spring of 1970. Textural analyses indicate that most offshore sediments contain greater than 70 percent clay-sized minerals (finer than four microns). The sedimentary units within the basin occur in three concentric units: a large clay unit in the center of the basin, a smaller silty clay unit 'shoreward' of the clay unit and a nearshore undivided unit consisting of sand, gravel, underwater 'outcrops' of glacial till and Glacial Lake Agassiz sediments and a thin discontinuous layer of silt and clay.

X-ray analysis of magnesium saturated, glycerol-treated unoriented slides of the fine clay fraction shows the mineralogy of the recent bottom sediments to be essentially homogeneous throughout the lake. The clays consist of approximately 80 to 85 percent randomly interstratified montmorillonite-illite and 10 to 20 percent kaolinite plus chlorite. The proportion of illite in the interstratified complex is 45 to 50 percent. The montmorillonite and illite are both dioctahedral. Differential thermal analysis indicates that the montmorillonite-illite interstratification consists of 'normal' illite - 'abnormal' montmorillonite with the direction of transformation being illite converting to montmorillonite. The dominant exchange ion on the montmorillonite is calcium.

The mineralogy of the Lake Winnipeg sediments agrees, in general, with that found by other researchers for the Cretaceous Shales, surface deposits and soils of Western Canada; and from this it would appear that little or no diagenetic changes have occurred in the clay minerals from the Cretaceous Shale source through the sequence of glacial erosion and redeposition as tills and glacio-lacustrine clays, pedogenic processes of soil formation, erosion of the soil and finally to deposition in Lake Winnipeg.

The rate of sedimentation calculated from suspended load data of the Red River is approximately 0.5 millimetres per year over the entire area of the south basin.

156. LAPOINTE, M.F.
1984: Patterns and Processes of Channel Change, Mackenzie Delta, N.W.T.; Progress Report (1983-84), Northern Hydrology Section, Surface Water Division, National Hydrology Research Institute, Environment Canada, 52 p.

ABSTRACT:

In 1983, a study was initiated of fluvial processes in the Mackenzie Delta. Between spring break-up and autumn low-flows, reconnaissance observations of channel conditions and processes were carried out mainly in the eastern-middle Delta, along Napoiak Channel to Shallow Bay and along East Channel and beyond to Point Separation. Preliminary conclusions on channel morphology, channel shifting and sediment transport are presented, based on reconnaissance and previously published data. Further research avenues are also discussed.

Characteristics of delta channel morphology confirmed by the author's bathymetric surveys include widespread "inner channels" as well as chaotic "hole and mound" zones on channel beds. Analysis of published cross-sectional data also suggests that channel depths increase particularly slowly with increasing widths in the Mackenzie Delta. Extensive 30-year air photo comparisons disclose rapid shifting along Middle Channel, which contrasts with subdued shifting along most other Delta channels. The study of these shifting patterns as well as observations of erosion processes during and after breakup suggest that flow strength may exert the main control on channel shifting, while hydrothermal and ice-run erosion appear to play minor roles. Exploratory bed material sampling supports a model of summer-long sand evacuation from distributary channel beds, with the morphology of distributary junctions playing a major role in controlling the sand supply. Avenues for further research include the genesis of "channel within channel" cross-sections, the controls on distributary abandonment, as well as further testing of the conclusions on channel shifting and sediment transport.

157. LAPOINTE, M.F.
1985: Aspects of Chennal Bathymetry and Migration Patterns in the Mackenzie Delta, N.W.T.; Report, Cold Regions Section, Surface Water Division, National Hydrology Research Institute, Environment Canada, 22 p.

ABSTRACT:

Detailed bathymetric surveys conducted in 1984-1985 have clarified the geometry and distribution of some scour holes and lateral shelves on channel beds in the eastern - central Delta. Most deep scour holes occur in tight bends, as in common in fluvial environments. Nonetheless, maximum depths attained can be striking (e.g. 16 m), even in smaller distributary channels (90 m width); furthermore these holes are generally located right at bend apex and close to the inner bank, rather than towards the outer bank and somewhat downstream from the apex, as in most sand and gravel-bed meanders. Scour holes have also been observed in a straight channel reach, where their distribution and geometry appear to be partly independent of flow structure. This suggests that inhomogeneities in the strength of bed materials may play a role in shaping some of these holes. The detailed surveys also show that genuine lateral shelves, lying between channel banks and thalweg, although they occur locally are not widespread in the small channels surveyed. To determine the long-term stability of the scour holes (and their potential for damage to sub-bed installations) the mechanisms creating them will have to be better understood.

Detailed 34-year shifting patterns were also mapped over hundreds of bends in the Delta, using large scale airphoto coverage acquired in September of 1984. An attempt was made to analyse the shifting patterns in terms of controlling variables such as channel width, local curvature and bank materials, using data from 7 particularly long channel reaches in the southwest area of the Delta. The results indicate that peak meander migration rates average, over many bends of various curvature, some 0.5% of channel width, per year, in this area of the Delta. Between - bend variations in peak shifting along a given reach can only be weakly explained in terms of the simple variable "bend curvature at apex", however. Peak shifting tends to decrease along with apex curvature, as has been documented elsewhere, although much scatter remains and considerable shifting may occur in surprisingly gentle bends. It is not possible to clearly explain this scatter on the basis of bank material variability inferrable from air photographs and further research into field conditions and processes would be necessary if reasonable predictions of local channel shifting rates are desired in the Delta.

158. LAST, W.M.
1982: Holocene Carbonate Sedimentation in Lake Manitoba, Canada; Sedimentology, Vol. 29, p. 691-704.

ABSTRACT:

The carbonate mineral suite of the modern offshore bottom sediment of the South Basin of Lake Manitoba consists mainly of high magnesian calcite and dolomite with minor amounts of low-Mg calcite and aragonite. The high-Mg calcite is derived from inorganic precipitation within the water column in response to supersaturation brought about by high levels of organic productivity in the basin. Both dolomite and pure calcite are detrital in origin, derived from erosion of the surrounding carbonate-rich glacial deposits. Aragonite, present only in trace amounts in the offshore sediments, is bioclastic in origin. The upward increase in the amount of magnesian calcite in the post-glacial sediment record is attributed to increasing photosynthetic utilization of CO_2 in the lake. Stratigraphic variation in the amount of magnesium incorporated into the calcite lattice is interpreted as reflecting a variable magnesium input to the lake from groundwater and surface runoff, and possibly variable calcium removal in the precipitating lake water. The effects of lonf-term chemical weathering at the source and size segregation explain the changes in dolomite content throughout the section.

159. LAST, W.M.
1984: Modern Sedimentology and Hydrology of Lake Manitoba, Canada; Environmental Geology, Vol. 5, No. 4, p. 177-190.

ABSTRACT:

Lake Manitoba, North America's thirteenth largest lake, occupies a glacier-scoured basin in south-central Manitoba. Despite its large size, the lake is extremely shallow with a mean depth of 4.5 m. The lake can be subdivided into two connected but distinctly different basins, a small, irregular-shaped North Basin and a much larger and smoother South Basin. Most of the water inflow is from the Waterhen River (42% of the inflow) and from precipitation directly on the lake's surface (40%), while nearly 60% of the outflow is by evaporation. Lake Manitoba water is alkaline and brackish with the salinity dominated by sodium and chloride ions.

The surficial offshore deposits of the main South Basin of the lake consist mainly of silt and clay-sized sediments composed of detrital components (clay minerals, quartz, carbonates, and feldspars) and endogenic/anthigenic components (carbonates, sulfides, and organic matter). In addition to these modern sediments, several areas of relict fluvial-shoreline sand and till deposits occur in the South Basin.

The lacustrine processes presently operating in Lake Manitoba reflect the influence of (1) the extreme shallow depth of the lake, (2) the basin morphology, and (3) the water chemistry. In addition, land clearing and increased watershed drainage have resulted in substantially increased sedimentation rates in the South Basin during the past century.

160. LAST, W.M.
1984: Sedimentology of Playa Lakes of the Northern Great Plains; Canadian Journal of Earth Sciences, Vol. 21, No. 1, p. 107-125.

ABSTRACT:

The semi-arid plains of western Canada and northern United States contain a large number of saline and hypersaline lakes, with many of the shallow lakes exhibiting characteristics. For over 60 years a number of these playas have provided a source of valuable industrial minerals. The present study deals with the modern sediments and sedimentary processes operating in selected playa basins located throughout the northern Great Plains region.

The playas generally occupy small, closed basins commonly having an elongate, riverine shape. Most of the brines are dominated by sodium, magnesium, and sulfate ions; however, examples of lakes rich in chloride and bicarbonate ions are also present. Significant variation in the brine chemistry can exist on a seasonal as well as a diurnal basis. The modern sediments of the playas consist of: (1) very soluble salts of mainly sodium and magnesium sulfates and carbonates; (2) sparingly soluble precipitates, including calcite, protodolomite, gypsum, and mixed layer clays; (3) detrital minerals consisting dominantly of quartz, carbonates, feldspars, and clays; and (4) organic matter.

Much of the physical and mineralogical character of the playas is due to processes that are largely of a chemical nature and are associated with either evaporative concentration of the brines or groundwater discharge. The most significant processes include: cyclic flooding and desiccation of the playa surface, formation of salt crusts, efflorescent crusts, spring deposits, and intrasedimentary salts, formation of solution pits and chimneys, wind displacement of brines, and periodic detrital sedimentation by sheet flow and wind. These processes combine to create a very dynamic modern depositional environment. The establishment and prolonged maintenance of delicate physical and chemical equilibria have allowed the deposition of over 40 m of salt in some basins.

161. LAST, W.M. and SCHWEYEN, T.H.
1982: Sedimentology and Geochemistry of Saline Lake of the Great Plains; In: Saline Lakes, U.T. Hammer Editor, Proceedings of the 2nd International Symposium on Athalassic (Inland) Saline Lakes, Saskatoon, June 24-28, p. 245-263.

ABSTRACT:

Southern Saskatchewan and portions of adjacent Alberta, North Dakota and Montana are occupied by hundreds of saline and hypersaline lakes ranging in size from small prairie potholes (less than 1 sq.km.) to relatively large bodies of water (greater than 300 sq.km.). From a sedimentological perspective, distinction must be made between two basic types of saline lakes; playas and perennial lakes. Calcium, sodium and magnesium sulfates, carbonates and bicarbonates form as chemical precipitates in lakes with more concentrated brines. In addition, experimental data suggests mixed layer smectites may form authigenically in some lakes. Clastic sediments in the salt lakes consist mainly of silt and clay-sized quartz, feldspars, carbonates and clay minerals. The dominant physical and chemical processes which are responsible for and act upon the sediment vary widely, mainly in response to basin morphology and brine chemistry. Evaporative concentration and significant groundwater contributions affect all the saline lakes. However, other processes are different in the two basic types of basins. The playa lakes are influenced by: evaporitic pumping and the formation of efflorescent crusts and intrasedimentary crystals, cyclic wetting and drying, precipitation of highly soluble saly layers, and influx of clastic debris by sheetflood and wind. In contrast, in the permanent lakes, precipitation of sparingly activity, seasonal temperature fluctuations and brine mixing. In addition, many of the permanent lakes undergo freeze-out precipitation of very soluble salts under a winder ice cover. Detrital sediments are distributed within the basins by normal lacustrine processes, including shoreline deposition and erosion, turbidity flow and pelagic fallout.

162. LAST, W.M. and TELLER, J.T.
1983: Holocene Climate and Hydrology of the Lake Manitoba Basin; In: Glacial Lake Agassiz, Edited by J.T. Teller and L. Clayton, Geological Association of Canada, Special Paper No. 26, p. 333-353.

ABSTRACT:

Lake Manitoba is a large, shallow remnant of Lake Agassiz that came into existence when Lake Agassiz fell from the high-water Emerson Phase after 9500 B.P. Sediment in the Lake Manitoba basin provides evidence of climatic and hydrologic changes in the region throughout the Holocene. From about 9000 to 4500 B.P., the level of Lake Manitoba fluctuated in response to climate and differential isostatic rebound. The basin became dry several times during this period, resulting in the formation of weakly developed soils on the lake floor. During episodes of relatively high water, silty and clayey lacustrine sediment rich in Mg-calcite accumulated in the deepest part of the basin. Non-arboreal prairie-type vegetation was dominant in the region during this period, reaching a maximum before 7000 B.P.

This episode of relatively dry conditions in the basin came to an end about 4500 B.P. when the Assiniboine River was diverted into the Lake Manitoba watershed. In addition to establishing a positive hydrologic budget for the lake, this major influx of water created a sandy delta at the mouth of the river. Elevated levels of magnesium were incorporated into the precipitated calcite of the offshore sediments in response to the increased Mg/Ca ratio derived from the flushing of magnesium from the Assiniboine River watershed. Although the Assiniboine River was diverted out of the Lake Manitoba drainage basin about 2200 B.P., water levels in the southern part of the lake have remained relatively constant, mainly because of a gradual shift toward a cooler and wetter climate and possibly because of continued rebound of the northern outlet. The loss of the Assiniboine River influx resulted in a reduced Mg/Ca ratio in the Mg-calcite. The deltaic sediments were partially reworked into a 33 km-long barrier island that now separates Delta Marsh from the main lake basin.

163. LENGELLE, J.G.

1976: Antropogenic Erosion Swan Hills, Alberta; Report Submitted to the Environment Conservation Authority of Alberta, 40 p. + Appendices.

ABSTRACT:

In this report the author discusses the problem of erosion in the Swan Hills, Alberta. Ten test areas were examined the major factors (slope geology) influencing erosion.

Methods employed in the past to correct erosional problems are discussed as well as future preventative measures.

It is concluded that an in-depth knowledge of erosional processes is essential when applying curative measures because blind application of so called cures are a waste of effort and money.

164. LUK, S.-H.

1975: Soil erodibility and erosion in part of the Bow River basin, Alberta; Unpublished Ph.D. Thesis, Department of Geography, University of Alberta, Edmonton, 422 p.

ABSTRACT:

This thesis attempts to collect basic data on soil erodibility and to test the applicability of laboratory simulation results to field studies of soil erosion. Few similar studies exist.

Within five sub-drainage basins, 17 one square-mile (2.59 km^2) units in the Bow River Basin above Bassano Dam were selected for study. These areas encompass the landscape spectrum from the mountains to the plains in Southern Alberta.

Following field mapping of the units according to a parametric system 153 samples were collected. Samples were tested for soil erodibility, aggregate size, texture, organic carbon content, and bulk density. For soil erodibility tests, the Edmonton-pattern rainfall simulator was used. Rainfall intensity was held constant at 102 mm/hr. Each sample had three runs of 30 minutes each, and soil moisture, slope angle, and cover density were varied. For the first two runs, total soil loss ranges from 1917 to 2490 g/m^2.

The data were analyzed by multiple regression techniques, and a simplified prediction equation using slope angle, cover density, aggregate size, and organic carbon content as the independent variables was established. About 80 percent of the total variation in laboratory simulated soil loss is explained by this equation.

Thirty erosion plots of about 1 m^2 in size were installed in the fall of 1972. These plots were only serviced one to three times in 1973. A more intensive sampling program for 16 plots was carried out in the summer of 1974. Total amount of measured soil loss for the season ranges from 6.1 to 94.5 g/m^2. About 40 to 50 percent of the total variation in measured soil loss is explained by the independent variables: raionfall amount, cover density, aggregate size, and bulk density.

With reference to constant rainfall amount and cover density, the laboratory simulation model was tested against observed field soil loss. The correspondence is generally good, and the coefficients of correlation range from 0.5 to 0.7.

Since the laboratory simulation model is substantiated by field data, the results are generalized to cover all 17 units studied. Plotting of unit soil erodibility shows a reduction in erodibility from the plains to the foothills and a slight increase again towards the mountains. The pattern appears to be explanable in terms of regional environmental characteristics. Unit soil erosion potential shows a similar pattern.

Drainage basin relative erosion rates were evaluated by considering mean soil erodibility, mean ground slope, mean cover density, and relative rainfall erosivity. The computed results seem consistent with available sediment yield records.

From these results, the deduced present rate of sedimentation at the Bassano Dam is much lower than the unadjusted long term mean. Major sources of sediment supply are (a) excessively erodible glacial or alluvial deposits and bedrock along major drainage channels in the upper foothills; (b) steeply sloping coulee sides, ditches, and cultivated land on moderate slopes in the prairies; and (c) cultivated and poorly grazed areas in the foothills where rainfall erosivity and sediment delivery rates are considerably higher than in the prairies.

165. MACKAY, G.H.
1970: A quantitative study of the geomorphology of the Wilson Creek Watershed, Manitoba; Unpublished M.Sc. Thesis, University of Manitoba, Winnipeg, 42 p. + Appendices.

ABSTRACT:

This thesis, which fulfills part of the requirements for a degree of M.Sc. at the University of Manitoba, presents the results of a study into some aspects of the geomorphology of the Wilson Creek Experimental Watershed. Data that has been gathered in the watershed over the past decade has been studied to determine rates of erosion in the escarpment portion of the watershed and rates of deposition in the Wilson Creek Delta.

Studies based on sediment transport data were made to determine the average annual rate of sediment transport over the past ten years which includes the influence of a headwater detention basin. Studies were also made to determine the effect of the headwater reservoir in reducing the average annual sediment discharge.

The annual cost of headwater storage in the Wilson Creek Experimental Watershed was determined and compared to the reduced annual maintenance costs in the artificia drain through the Wilson Creek Delta. It was found that headwater storage cannot be justified on sediment discharge reduction alone. However, evidence indicates that reduct on in flood damage accruing to such storage is probably significant and warrants further study.

166. MACKAY, G.H. and STANTON, C.R.
1964: Wilson Creek Study: Erosion and Sedimentation Control; Proceedings of the Canadian Hydrology Symposium No. 4 on Research Watersheds, p. 41-75.

ABSTRACT:

This paper sets out the problems of rapid runoff with attendant erosion and sedimentation which occur in the Wilson Creek Watershed on the eastern slopes of the Riding Mountain area. The history of governmental involvement in drainage and flood control in the escarpment and surrounding areas is traced up to the present time. A description of the physical aspects of the escarpment area in general, and Wilson Creek in particular, is followed by a more detailed discussion of the runoff, erosion and sedimentation problems. The program of investigation on Wilson Creek is discussed under two main headings. The first of these refers to runoff measurement and control while the second deals with sediment measurement and control. The runoff section describes the hydrologic and meteorologic instrumentation together with investigations into vegetation problems. The construction and operation of headwater detention reservoirs is also covered. The sediment section describes approaches to the measurement of transported shale and covers as well a number of approaches to streambank erosion control.

167. MACKENZIE RIVER BASIN COMMITTEE
1981: Mackenzie River Basin Study; Report, 231 p. + 9 Supplements.

NOTE: Supplements include:

1) Sensitive areas: literature review, Watdoc references
2) Alluvial ecosystems
3) Spring break-up
4) Hydrometeorologic network design
5) Hydrometeorologic network design: background reports
6) Slave River Delta
7) Athabasca Sand Dunes in Saskatchewan
8) Daily hydrologic model user manual
9) Water quality

168. MALLANDAINE, A.I.
1980: The Effect of Land Uses on Lake Water Quality, Sturgeon Lake, Alberta; Unpublished M.Sc. Thesis, Department of Geography, University of Alberta, Edmonton, 247 p.

ABSTRACT:

This study was conducted in the Sturgeon Lake drainage basin. The objectives were to increase the water quality data base and to relate the findings to land uses in the watershed. This would improve the reliability of management plans for the lake area. A resource inventory of the watershed components was compiled and correlated with water quality data collected from a dozen sample sites over a three month period. It was found that the lake is naturally mildly eutrophic with most of the nutrient inputs coming from natural sources. Primary productivity in the lake was found to be limited by physical factors such as color, turbidity and self-shading rather than nutrient availability. Lake levels are maintained at an excessively high level in order to maintain a water supply for the town of valleyview. As a result, good beach areas are flooded for most of the year and many shorelines are being eroded. Alternate means of supplying water to the town are suggested. Development capacity calculations indicate that the lake is near the optimum level of development, however possible areas for some development are recommended. Recommendations are also made regarding wetland drainage and lake restoration techniques. Possible subject areas meriting further study are suggested.

169. MANITOBA DEPARTMENT OF NATURAL RESOURCES
1981: Suspended Sediment Data Acquired by the Manitoba Water Resources Branch; Internal Report Prepared by Water Management Services, Winnipeg, 110 p.

ABSTRACT:

This report lists the suspended sediment data collected by the Manitoba Water Resources Branch during 1974-1979.

170. MARTZ, L.W.
1978: The Sediment Yield of Spring Creek Watershed; Report 1978/83, Alberta Environment, Research Secretariat, 101 p.

ABSTRACT:

The sediment regime of Spring Creek Watershed, a 112.7 km^2 wilderness area in west-central Alberta, was assessed using streamflow records and suspended sediment and solute concentration measurements made on Spring Creek and five of its tributaries from 1967 to 1977.

Most of the watershed contributes practically nothing to the sediment yield. 90% of the sediment yield is derived from a 1.5 km^2 area near the watershed mouth; a zone of geomorphic disequilibrium developed in response to past changes in the local base level. Older, higher level disequilibrium zones on the tributary streams provide most of the remaining sediment yield.

On average, 76% of the annual sediment yield is output during spring runoff and the sediment discharge of 18 days per year accounts for 90% of the annual sediment yield. Combining spatial and temporal aspects shows that over 80% of the sediment yield is derived from 1.5% of the watershed area in less than 5% of the time.

Sediment rating curves give reasonably good prediction of sediment concentration from streamflow rates for Spring Creek, but not for its tributaries. The sediment streamflow relationship observed for Spring Creek is largely defined within the major sediment source area near the watershed mouth.

Differences between spring and summer rating curves are minor and variations in mean monthly sediment yield are controlled by variations in monthly flow characteristics.

The input of the construction of a pipeline right-of-way across Spring Creek was evaluated. This disturbance of .004% of the watershed area produced a 36% increase in sediment yield.

Recommendations for further research and some guidelines for land managers are presented.

171. MARTZ, L.W.
1979: Sediment Yield of Spring Creek Watershed, Alberta; Unpublished M.Sc. Thesis, University of Alberta, Edmonton, 114 p.

ABSTRACT:

The sediment regime of Spring Creek Watershed, a 112.7 km^2 wilderness area in west-central Alberta, was assessed using streamflow records and suspended sediment and solute concentration measurements made on Spring Creek and five of its tributaries from 1967 to 1977.

Most of the watershed contributes practically nothing to the sediment yield. Ninety percent of the sediment yield is derived from a 1.5 km^2 area near the watershed mouth; a zone of geomorphic disequilibrium developed in response to past changes in the local base level. Older, higher level disequilibrium zones on the tributary streams provide most of the remaining sediment yield.

On average, 76% of the annual sediment yield is output during spring runoff and the sediment discharge of 18 days per year accounts for 90% of the annual sediment yield. Combining spatial and temporal aspects shows that over 80% of the sediment yield is derived from 1.5% of the watershed area in less than 5% of the time.

Sediment rating curves give reasonably good prediction of sediment concentration from streamflow rates for Spring Creek, but not for its tributaries. The sediment-streamflow relationship observed for Spring Creek is largely defined within the major sediment source area near the watershed mouth.

Differences between spring and summer rating curves are minor and variations in mean monthly sediment yield are controlled by variations in monthly flow characteristics.

The impact of the construction of a pipeline right-of-way across Spring Creek was evaluated. This disturbance of .004% of the watershed area produced a 36% increase in sediment yield.

Recommendations for further research and some guidelines for land managers are presented.

172. MARTZ, L.W. and CAMPBELL, I.A.

1980: Effects of a Pipeline Right-of-way on Sediment Yields in the Spring Creek Watershed, Alberta; Canadian Geotechnical Journal, Vol. 17, No. 3, p. 361-368.

ABSTRACT:

Very few data are available on the sediment yield of Alberta watersheds especially in the northern portion of the province. In the 175 000 sq.km. Peace River basin, which covers about 25% of Alberta, sediment data are collected regularly at only four stations. One of these is the 112.7 sq.km. Spring Creek watershed. In 1977 a pipeline was installed near the mouth of Spring Creek, disturbing an area of about 5000 sq.m. near the stream channel. The effects of this were to increase local sediment yields by over 1600 Mg in a 4 month period. This compares with regional averages for the Peace River basin of 18-88 Mg per sq.km. per year. The study indicates the magnitude of spatial variation of sediment production and shows some effects of geotechnical activities on sediment yields.

173. MATHEWS, W.H.

1964: Sediment Transport from Athabasca Glacier, Alberta; International Union of Geodesy and Geophysics, International Association of Scientific Hydrology, Proceedings of the Symposium on Land Erosion, Precipitations, Hydrometry and Soil Moisture, Berkeley, August, 1963, I.A.S.H. Publication No. 65, p. 155-165.

ABSTRACT:

Athabasca Glacier (13.5 km^2) discharges meltwater and icebergs into Sunwapta Lake (0.13 km^2) which also receives meltwater from 4.9 km^2 of smaller glaciers and snowmelt and runoff from 9.8 km^2 of rocky, talus and moraine covered slopes.

For one 24 hour period (July 22-23, 1957) an estimated 380 metric tons of sediment finer than 0.625 mm was brought into Sunwapta Lake by two glacial streams which averaged in silt concentration from 775 ppm (early morning) to 3250 (mid afternoon). Sediment plans on the lake bottom collected silt and clay sizes at rates of from 0.001 to 0.015 gm/cm^2 day, from which a total daily accumulation of 125 tons was estimated. Escape from the lake was determined at 4 and 7 tons per day by two separate estimates.

For the same 24 hour period an estimated 190 tons of sand were carried to the Lake an estimated 125 tons settled on the lake floor, and no sand was carried in suspension from the lake.

Sampling problems clearly account for most of the discrepancies in the above Figures, but the effectiveness of even a small lake as a sediment trap is nevertheless clearly indicated.

For the 1957 season the movement of sediment from Sunwapta Lake was determined as:

	Transport, metric tons		Mean Concent. in Stream Water
	Measured May 21-Oct. 8	Possible Total Apr. 28-Oct. 31	
Sand size	nil	nil	nil
Silt & Clay sizes	778	840	33 ppm
Dissolved matter	1,311	1,500	59 ppm

High concentrations (70-113 ppm) of dissolved matter occurred early in the season, associated with low discharge. High concentrations of suspended sediment were associated with high discharge and occurred late in the summer.

174. **McCANN, S.B., COGLEY, J.G., BLACHUT, S.P., BALLANTYNE, C.K, BENNETT, B.G.**
1975: Hydrology and Sediments of the "Sverdrup" and "Schei" Rivers with Particular Reference to Ice Marginal Drainage Conditions, Hydrological Studies, South Central Ellesmere Island: Section A of a Report on Investigations Undertaken in the Vendom Fiord Area in 1974; Inland Waters Directorate, Department of the Environment, 283 p.

ABSTRACT:

Results of a second field season investigating the hydrological conditions along part of the western margin of the Ellesmere Ice Cap are presented, and compared with the previous season. The study was carried out in the area at the head of Vendom Fiord (78°03'N, 82°17'W) during the period June 19-August 21, 1974.

The main focus of the work concerned the hydrologic regimes of the two principal streams, the Sverdrup River and the Schei River, which drain from the ice cap into the head of Vendom Fiord, and with the nature and drainage behaviour of a series of ice margin lakes which contribute to the Sverdrup system. The 1974 season was much drier than 1973 (12 mm precipitation v 91 mm) and the seasonal hydrographs for the two streams show no dramatic responses to precipitation, such as were recorded in the earlier year. The Sverdrup hydrograph exhibits an early phase of high flow between 12-16 July, with a maximum discharge of 228 m^3 sec^{-1} on 13 July, and a late season glacier melt peak between 27 July and 5 August, together with high flows on particular days until 19 August. The ice margin lake drainage commenced on 13 August (c.f., 1 August in 1973) and the volumes of water involved were much smaller than in the earlier year. In the light of the 1974 observations the discharge figures cited in an earlier report for the Sverdrup River during and after the jōkulhlaup of 1 August, 1973 have been modified.

The ice margin lake system was examined in detail throughout the 1974 season. A full data set of meteorological, limnological, glaciological and hydrological observations provides a record of the filling and drainage behaviour of the principal lake, and allows conclusions to be drawn about the nature of the ice dam and the drainage mechanisms.

The hydrograph of the Schei River exhibits a similar seasonal pattern to that of the larger Sverdrup River. Separate hydrographs were obtained in 1974 for the three tributaries of the Schei River, which enable the different components of total discharge to be separated: glacier melt *per se* accounted for 55% of the total runoff in 1974. The more intensive investigation of the Schei River and its drainage basin in 1974 also involved studies of sediment load and availability, and of the characteristics of the Schei sandar. Sandar are an important dynamic landscape unit in the study area and the observations on the Schei are considered representative of similar conditions elsewhere along the ice margin.

175. McCART, P.J., CROSS, P.M., GREEN, R, MAYHOOD, D.W., TSUI, P.T, McCART, P.J. and GREEN, R.H.
1981: Effects de l'envasement sur l'écologie du lac Ya-Ya, T.N.-O.; Etude environnementale no. 13, Ministère des affaires indiennes et du Nord Canadien, 226 p.

ABSTRACT:

L'envasement est sans doute la perturbation environnemental;e la plus courante des habitats aquatiques, provoquée par les activités de mise en valeur du Nord. Le lac Ya-Ya sur l'île Richards, dans le delta du Mackenzie, (Territoires du Nord-Ouest) a été choisi comme site d'étude des effets de la charge des sédiments en suspension sur les écosystèmes des lacs. L'objectif principal de l'étude était de déterminer les conséquences de la sédimentation sur divers niveaux trophiques, notamment les poissons, dans le

cadre d'un écosystème de lac boréal. D'autres objectifs connexes consistaient à élaborer, d'après les résultats de l'étude. Un modèle permettant de mieux prévoir et quantifier l'impact de l'envasement sur les écosystèmes des lacs dans le Nord et a proposer des critères quantitatifs définissant les niveaux de sédimentation acceptables, lesquels pourraient être utilisés dans la réglementation des projets de développement dans le Nord. Les difficultés rencontrées dans l'application des résultats sont évaluées dans les conclusions.

176. McCULLOUGH, G.K. and NEWBURY, R.W.
1985: Shoreline Erosion and Nearshore Sedimentation of Glacio-Lacustrine Sediments, at Southern Indian Lake, Manitoba; Proceedings of the Canadian Coastal Conference 1985, 13-16 August, St. John's, Newfoundland, p. 71. (abstract only)

ABSTRACT:

In 1976, a 3 m impoundment of Southern Indian Lake exposed glacio-lacustrine sediments in permafrost to wave erosion. Erosion proceeds in a cycle of melting, undercutting and slumping of bank materials and tow erosion of the melting and fractured debris. Stable beach forms are not produced until more resistant bedrock is encountered or sand is imported by longshore drift from pro-glacial deposits intersecting the shoreline. Measured rates of shoreline erosion range up to 12 m/y and 23 m^3/m shoreline length/y. More than 80% of this eroded material is initially deposited within 300 m of the shoreline at 2-7 m depth. Erosion at the water's edge produces aggregates of clay sediment ranging from silt to pebble size. These are transported offshore as bedload to the limit of entrainment. At one monitoring site with a maximum fetch of 11 km, maximum aggregate size is 6 mm at 2 m depth, 0.5 mm at 3 m, and 0.1 mm at 4.8 m. Further erosion of these deposits proceeds by abrasion of the aggregates, bringing primary clay and silt particles into suspension. Maximum sizes of sediments suspended in the water column are <.05 mm, and 60% of particles are smaller than .001 m. Transient nearshore deposition will extend the effect of increased turbidity in Southern Indian Lake at least a decade beyond the term of intensive shoreline erosion.

177. McDONALD, B.C. and BANERJEE, I.
1971: Sediments and Bed Forms on a Braided Outwash Plain; Canadian Journal of Earth Sciences, Vol. 8, No. 10, p. 1282-1301.

ABSTRACT:

Sediments and bed forms from three braided outwash plains and one steep non-braided mountain stream in the Rocky Mountains of Alberta are compared to sediments and structures exposed in a paleo-outwash sequence.

Channel sediments are subdivided into (a) pool facies; ripple- and parallel-laminated silty sand, with current crescents around isolated stones; and (b) riffle facies; parallel-stratified gravel and silt or silty sand.

'Transverse ribs' constitute a bed form typical of riffle portions of channels. This bed form occurs as a train of regularly spaced pebble, cobble, or boulder ridges oriented transversely to the flow. Locally, the pebbly ribs are separated by, and rest on, a stone-free silty substratum. It is suggested that transverse ribs constitute a common equilibrium bed form in higher gradient riffle portions of gravelly alluvium.

Longitudinal bars dominate interchannel areas of the modern outwash plains. They consist of coarse, poorly sorted gravel, either massive or exhibiting crude horizontal stratification. The paleo-outwash, composed of finer-grained and better sorted gravel, is characterized by sets 5 to 30 cm thick of cross-stratified sand and by sets 75 to 82 cm thick of cross-bedded pebble gravel. These may be related to progradation of dunes and bars, respectively.

Standard deviations of channel azimuths in modern outwash plains are appreciable less than that recorded by cross-stratification measurements in the time-transgressive sequence of paleo-outwash. This is partly due to the braided system of channels having swept from side to side across the plain through time.

178. McLAREN, P.

1981: River and Suspended Sediment Discharge into Byam Channel, Queen Elizabeth Islands, N.W.T., Canada; Arctic, Vol. 34, No. 2, p. 141-146.

ABSTRACT:

During 1974, a stream from a small drainage basin (117 km^2) on the east coast of Melville Island discharged approximately 1.63 x 10^7 m^3 water containing 7.08 x 10^7 kg suspended sediment. Because nearby basins show hydrological similarity, these data can be extrapolated to provide an indication of the total suspended sediment discharge into the adjacent channels. The results suggest that much of this sediment is not deposited in the channels; rather it is incorporated into the active delta fronts or possibly transported out of Byam Channel above a pycnocline.

The values agree well with a hydrological study on nearby Bathurst Island where predicted discharge values for both runoff and suspended sediment are within an order of magnitude of those measured. Recent attention has focussed on the Mecham River which flows into Bridport Inlet, the site of a proposed LNG terminal which is to be situated on an active delta front. Values extrapolated from this study indicate that design criteria must considered typical runoffs of 1.2 x 20^8 m^3 with peak mean daily discharges in excess of 9.0 x 10^6 m^3/day and suspended sediment loads of 5.0 x 10^8 kg/year.

179. McLAUGHLIN, F. and YUZYK, T.R.
1981: Lake Diefenbaker, Saskatchewan: A Case Study of Reservoir Sedimentation; Canadian Water Resources Journal, Vol. 7, No. 2, p. 391-392.

ABSTRACT:

Effective reservoir management requires a viable data collection program to determine the distribution of sediments, sedimentation rates, sediment characteristics, and how they affect the reservoir capacity. With this in mind a program was established for Lake Diefenbaker in 1964, as an International Hydrological Decade Project Sask-2 and entitled, "Delta Formation and Sedimentation in Lake Diefenbaker". The program consisted of establishing 38 ranges, which would be profiled at a determined time interval. In 1972, the conventional cross section was replaced by an area survey with the introduction of an Automated Hydrographic Data Acquisition System (HYDAC). To supplement the survey data, bed material and suspended samples were collected at each range. An analysis of contour maps, contour difference maps and capacity table produced from the 1975 and 1978 data collected from Lake Diefenbaker revealed a low sedimentation rate. All the sedimentation that is occurring is located below the low water level. Between the low water level and full supply level all the ranges have shown an increase in capacity, due to extensive bank erosion. These findings and the results from a further analysis of the sediment sampling program will be discussed in detail as to how they may affect reservoir management. A review of Lake Diefenbaker's data collection program will also be examined in terms of its effectiveness to monitor the process.

180. McLEAN, D.G. and BECKSTEAD, G.R.
1981: Long-term Effects of a River Diversion on the Regime of the Milk River; Proceedings of the 5th Canadian Hydrotechnical Conference, Fredericton, New Brunswick, Canada Society of Civil Engineers, p. 373-394.

ABSTRACT:

Diversion of flow from the St. Mary River into the Milk River basin commenced in 1917 and has had a pronounced effect on the receiving channel. The impact of this diversion on the morphology of the Milk River was assessed by comparing historical surveys and air photographs and analyzing available hydrologic and suspended sediment data. The major effects of the diversion included channel widening, increased cutoff activity and increased sediment yield.

181. McPHERSON, H.J.
1967: Morphology and Fluvial Processes of the Lower Red Deer Valley, Alberta; Unpublished Ph.D. Thesis, Department of Geography, McGill University, Montreal, 149 p.

ABSTRACT:

In this thesis the author provides a description and an explanation of the landforms present in the Lower Red Deer River valley. An historical evolution of the valley is presented. The author also examines river channel and floodplain characteristics and explains the variations that occur throughout the study length.

Results show that channel pattern and floodplain morphology are closely related. The floodplain surface, where the floodplain has been constructed by a river with a meandering pattern, consists of a series of low parallel arcuate ridges. Where the floodplain has been built by a braiding river, the floodplain surface is composed of a complex of low topographic highs and abandoned anabranches. The manner of floodplain formation in different parts of the valley depends on the mechanism of channel shift and the channel pattern. Where the river is meandering a systematic transfer of material occurs from the concave to the convex banks, resulting in the formation of point bars. Vertical accretion deposits are added to the floodplain surface during periods of overbank flow. In the channel segments where the river is braiding, the river as it migrates, successively abandons channels and these together with the alluvial islands, the anabranches formerly separated from the floodplain, are incorporated into the floodplain. The channels are infilled during flood periods and are built up gradually to the levels of the surfaces of the former alluvial islands.

182. McPHERSON, H.J.
1969: Flow, Channel and Flood Plain Characteristics of the Lower Red Deer River, Alberta; In: Geomorphology: Selected Readings, J.G. Nelson and M.J. Chambers Editors, Methuen, Toronto, p. 257-279.

ABSTRACT:

This paper provides the results of an analysis of the flow, channel and floodplain characteristics in a selected reach of the Lower Red Deer River, Alberta. These indicate that the river system exhibits very different characteristics upstream and downstream of the end of map sheet 72L/13. The upstream part is narrower and deeper than the downstream part. Suspended sediment load appears to the most important factor influencing stream morphology.

183. McPHERSON, H.J.
1971: Downstream Changes in Sediment Character in a High Energy Mountain Stream Channel; Arctic and Alpine Research, Vol. 3, No. 1, p. 65-76.

ABSTRACT:

Rapid downstream changes in particle size, form, sorting, and grain size distributions are demonstrated to occur in the bed sediments of Two O'Clock Creek, a small stream in the Canadian Rockies. These changes are related to distance from the stream mouth, bed slope, and rock lithology. Pebble size, maximum projection area, and sorting alter systematically downstream while pebble roundness and flatness do not change. Particle size, maximum projection area, roundness, and sorting correlate significantly with bed slope, with the larger, better rounded and more poorly sorted gravels occurring on the steeper channel segments. Rock lithology correlates more highly with pebble size, maximum projection area, roudness, and flatness than either distance from the stream mouth or local bed slope, proving it to be the single most important factor influencing particle character. The high degree of variance displayed by the relationships most probably reflects the addition of fresh material to the stream along its course.

184. McPHERSON, H.J.
1971: Dissolved, Suspended and Bedload Movement Patterns in Two O'Clock Creek Rocky Mountains, Canada, Summer, 1969; Journal of Hydrology, Vol. 12, No. 2, p. 221-233.

ABSTRACT:

During the summer of 1969, 12,850 tons of material were removed as suspended sediment load, 440 tons as dissolved load and 65 tons as bedload from Two O'Clock Creek Basin in the Canadian Rockies. This is equivalent to a surface lowering of the basin by 0.0195 inches per year, a figure which agrees very well with rates of denudation reported by researchers for other mountain areas. During the peak snow melt generated flood in early June, 87 per cent of the total sediment load was exported. Most of the remainder was transported out of the basin by a secondary high flow resulting from rainfall and snowmelt in early July. The single most intense rainstorm of the season on August 5 and 6 resulted in a minor increase in streamflow but no increase in sediment discharge.

185. McPHERSON, H.J.
1975: Sediment Yields from Intermediate-sized Stream Basins in Southern Alberta; Journal of Hydrology, Vol. 25, p. 243-257.

ABSTRACT:

Suspended sediment yields were determined for 36 basins and dissolved sediment yields for 21 intermediate-sized stream basins in southern Alberta, Canada. Calculation of long term mean sediment loads was based upon the establishment of sediment rating-curves for gauging stations at the basin outlets and the construction of a sediment duration curve from sediment rating and flow duration curves.

Mean yearly suspended sediment export ranged from 12.55 tons/sq.mile to 576.9 tons/sq.mile with 58% of the basins yielding less than 200 tons/sq.mile. These rates are in close agreement with values reported by others for western Canada. Dissolved sediment yields ranged from 0.89 to 286.6 tons/sq.mile per year with 50% of the catchments contributing less than 50 tons/sq.mile per year.

Relationships between sediment yields and geomorphic and hydrologic variables were subjected to regression analysis. Highly significant relationships were established between sediment yields, unit mean discharge, mean annual discharge, local relief, elevation and mean land slope. Mean land slope and unit mean discharge were the variables which gave the highest correlation coefficients. Predictive equations were developed which allow sediment yields to be detemined for ungauged catchments.

186. McPHERSON, H.J. and HIRST, F.
1972: Sediment Changes on Two Alluvial Fans in the Canadian Rocky Mountains; In: Mountain Geomorphology, O. Slaymaker and H.J. McPherson, Editors, Tantalus Press, Vancouver, p. 161-175.

ABSTRACT:

In the Kootenay plains area of the upper North Saskatchewan valley in the Canadian Rockies a series of well developed, often coalescing alluvial fans exist. This paper describes the variations in sediment character which occur over the surface of two of these fans and shows how these changes are related to fan surface slope, distance from the fan apex and lithology.

187. McPHERSON, H.J. and RANNIE, W.F.
1969: Geomorphic Effects of the May 1967 Flood in Graburn Watershed, Cypress Hills, Alberta, Canada; Journal of Hydrology, Vol. 9, p. 307-321.

ABSTRACT:

In May 1967, a flood which was at least 50 year flood occurred in Graburn watershed in the Alberta Cypress Hills. During the 6 day flood period from May 16th to May 21st, 1023 tons of sediment were removed in solution, 17 400 tons in suspension and 28 300 tons as bedload. An average thickness of 0.09 feet of fresh overbank material was deposited by the floodwaters. Gravel, as well as the more normal vertical accretion silt and clay material was laid down on the floodplain surface. Comparison of the rate of denudation calculated for the flood (0.0013 feet) with other reported rates, suggest that it is not as high as might be expected for a flood of this magnitude.

188. MILES, M.J.
1977: Coastal and Riverbank Stability on Banks Island, N.W.T., Canada; Proceedings of the Third National Hydrotechnical Conference, Canadian Society of Civil Engineers, Quebec City, May 30-31, 1977, p. 972-991.

ABSTRACT:

A reconnaissance of riverbank and coastal stability on Banks Island, N.W.T. was conducted during the summer of 1975. Field

observations indicate that there are three significant factors which affect the stability of banks formed in unconsolidated material which is permanently frozen:

1. the exposure of the bank to fluvial sediment removal;
2. the texture of the material composing the bank, and
3. the ice content of the frozen material underlying the ground surface.

Important modifying factors include the effect of nivation, the presence of ice wedges and the degree of vegetation cover. Rates of bank erosion as determined from field studies and interpretation of aerial photographs show a strong relationship to these parameters. Various combinations of grain size, ice content and effective exposure were found to result in the formation of distinctive bank morphologies. As many bank features are of sufficient size to be identified on aerial photography, a knowledge of the relationship between the morphology of a bank and its environmental and material characteristics is useful for predicting bank stability from air photographs.

189. MUIR, D.C.G.
1980: Determination of Terbutryn and its Degrading Products in Water, Sediments, Aquatic Plants, and Fish; Journal of the American Chemical Society, Vol. 28, No. 4, p. 714-719.

ABSTRACT:

A method is described for the determination of terbutryn 2-(tert-butylamino)-4-(ethylamino)-6-(methylthio)-s-triazine and several of its degradation products, N-deethylated terbutryn (DET), hydroxyterbutryn (HT), N-deethylated hydroxyterbutryn (DEHT), 2-(tert-butylamino)-4-(ethylamino)-s-triazine (EBT), and 2-(tert-butylamino)-4-amino-s-triazine (ABT), in samples from the aquatic environment. Water samples were extracted with dichloromethane, while sediment, aquatic plants, and fish tissues were extracted with aqueous acetonitrile. The hydroxytriazines were isolated by chromatography on a cation-exchange resin and cleanup on alumina and by high-pressure liquid chromatography. Recoveries of terbutyn, DET, HT, DEHT, ABT, and EBT from water (0.5-50 micro g/L) ranged from 76 to 120%. Terbutryn and DET recoveries from sediment, plant material, and fish tissues (0.05-0.9 micro g/g) ranged from 74 to 106%. HT and DEHT recoveries from sediment, plant material, and fish tissue (0.1-1.23 micro g/g) ranged from 62 to 124%.

190. MUIR, D.C.G. and YARECHEWSKI, A.L.
1982: Degradation of Terbutryn in Sediments and Water Under Various Redox Conditions; Journal of Environmental Sciences and Health, Part B, Vol. 17, No. 4, p. 363-380.

ABSTRACT:

A laboratory study was conducted to examine the degradation of terbutryn (2-(t-butylamino)-4-(ethylamino)-6-(methylthio)-s-triazine) in sediment and water under different redox conditions. Terbutryn degraded slowly in static aerobic systems (loosely capped flask, 25C) with half-life of 240 and 180 days in pond and river sediment, respectively. Degradation products, identified by co-chromatography on TLC and HPLC systems, included hydroxy-terbutryn, terbutryn- sulfoxide and N-deethyl terbutryn. Hydroxyterbutryn was the major degradation product in sediments and water representing 60-70% of the extractable radioactivity after 515 days incubation. Under nitrogen aeration in respirometer flasks (redox potential -46 to +210 mv) degradation of terbutryn was very slow with half lives greater than 650 days.

191. MUIR, D.C.G. and YARECHEWSKI, A.L.
1984: Degradation of Methoxychlor in Sediments under Various Redox Conditions; Journal of Environmental Sciences and Health, Part B, Vol. 19, No. 3, p. 271-295.

ABSTRACT:

The degradation of methoxychlor (14C-ring-labelled) was studied under laboratory conditions in lake and pond sediments (water-sediment ratio, 10-20:1) incubated under various redox conditions at 22.5 or 10C. Methoxychlor degraded rapidly in sediments with half-lives of less than 28 days under nitrogen aeration (Eh less than -50 mv), 49 to 55 days under static aerobic conditions and 115 and 206 days in air-purged flasks (Eh 220 to 464 mv). The major degradation products were dechlorinated methoxychlor (DMDD) and mono- and dihydroxy (demethylated) derivations of methoxychlor and DMDD. Dihydroxy-derivatives represented 15% of extractable radioactivity in pond sediments and 28% in lake sediments after 448 days of aerobic incubation. Under nitrogen aeration, mono- and dihydroxy-derivatives represented 44 to 65% of extractable 14C after 28 days incubation.

192. NANSON, G.C.
1972: Sediment Transport in Two Rocky Mountain Streams; Unpublished M.Sc. Thesis, Department of Geography, University of Alberta, Edmonton, 127 p.

ABSTRACT:

This thesis studies the pattern of sediment transport in two small streams in the Canadian Rocky Mountains, relating sediment transport to water discharge. Bed-load measurements are made using low weirs to trap sediment in both Two O'Clock and Bridge Creeks and in addition, bed-load basket sampler measurements and suspended load samples are taken in Bridge Creek.

Weir sedimentation results for measuring bed-load transport in Two O'Clock Creek show a close relationship between bed-load discharge and water discharge. The analysis of basket sampler results from Bridge Creek illustrates that the bed-load discharge/water discharge ratio is greater prior to the season's peak flow than after this peak. As a result, two bed-load rating curves are used in Bridge Creek, and both these show a close relationship between water discharge and bed-load discharge. The criticial water discharge required to entrain bed-load in Bridge Creek rose significantly after the peak flow.

Tentative basket sampler efficiencies determined from basket sampler and weir survey results on Bridge Creek indicate an increase in sampler efficiency as water and sediment discharge increase.

Four commonly used bed-load formulae are applied in both Bridge and Two O'Clock Creeks to predict bed-load discharges. As a result of the poor relationship between the predicted values and the measured bed-load discharges, it is concluded that the general application of bed-load formulae to small mountain streams will not provide an accurate estimation of bed-load.

The analysis of suspended sediment concentration/water discharge ratios in Bridge Creek shows a progressive decrease as the runoff season progresses. While the relationship between sediment concentration and water discharge shows considerable variation, the explained variance can be significantly increased if the number of days between the start of the runoff season and the time of sampling is also included in the analysis.

On the basis of qualitative observations in Bridge Creek catchment, the most plausible hypothesis to explain the decline of both bed-load and suspended load/water discharge ratios is the reduction of sediment supply to the stream channel. This supply is probably related to spring than geomorphic processes within the catchment.

193. NANSON, G.C.
1974: Bedload and Suspended-load Transport in a Small Steep, Mountain Stream; American Journal of Science, Vol. 274, p. 471-486.

ABSTRACT:

The sediment transport pattern was examined in Bridge Creek, a small, steep tributary of the North Saskatchewan River in the Rocky Mountains of west-central Alberta. Bedload per unit water-discharge was greater prior to the spring peak flow than after the peak, irrespective of whether samples were taken on a rising or falling stage. The critical discharge required to entrain bedload increased substantially after the peak flow.

The suspended-sediment concentration per unit water-discharge declined progressively as the runoff season continued. It is proposed that this decline in bedload and suspended-load concentration is the result of a seasonsal decrease in the intensity of geomorphic processes controlling sediment supply to the stream channel.

This finding contrasts the generally accepted belief that bedload is controlled by the hydraulic and bed characteristics of a stream. Apparently certain mountain streams are more than competent to transport the material supplied to them, but the limited period of rapid, seasonal, mass-movement restricts this supply to less than capacity.

194. NEAME, P.A., DEAN, J.R. and Zytaruk, B.G.
1981: Distribution and Concentrations of Naturally-Occurring Radionuclides in Sediments in a Uranium Mining Area of Northern Saskatchewan, Canada; Proceedings of the 2nd International Symposium on the Sediment/Freshwater Interface, Kingston, 15-18 June, Hydrobiologia, Vol. 91-92, p. 355-361.

ABSTRACT:

Uranium mining and milling operations can contribute to environmental degradation through the increased release of naturally-occurring radionuclides. However, studies of the interactions of these radionuclides with freshwater sediments have been limited. The present study examined the vertical distribution of uranium, thorium, radium-226, polonium-210 and lead-210 in undisturbed sediment cores collected in the vicinity of mining, milling and exploration activities. Uranium levels in surface sediments ranged from 1.9 to 5650 micro g per g. Ra-226 from less than 0.1 to 480 pCi per g and Pb-210 from 0.8 to 931 pCi per g in the samples reported here, with the highest values occurring downstream of waste rock disposal areas. Concentrations usually decreased with depth, and there was little evidence of any strong effect of bioturbation on radionuclide profiles at the scale examined here. Mathematical models of uranium and radium-226 adsorption and movement into the sediment were constructed, based on expected adsorption coefficients and estimated loading. The model predictions of radionuclide distribution with depth were qualitatively similar to those actually measured, but the predicted concentrations were generally lower than those observed, both in unaffected areas and in areas adjacent to uranium extraction activities.

195. NEILL, C.R.
1969: Bed Forms in the Lower Red Deer River, Alberta; Journal of Hydrology, Vol. 7, p. 58-85.

ABSTRACT:

Observations in the form of air photographs and echo soundings were made at various times over a period of 4 years on the Red Deer River near Duchess, Alberta. These revealed a complex system of both large- and small-scale features or wave forms on the sandy bed of the river. It is shown that the features, and with them the bed elevations at certain points, change considerably from time to time, and that the minor forms in particular change size rapidly in response to changes in flow. The observations are discussed in terms of some recent efforts towards classification of river-bed forms and towards relating their properties to hydraulic factors. It is suggested that very detailed and extensive field observations would be needed to fully describe the bed topography and its changes at similar locations, and that laboratory observations of bed-forms in flumes do not in general reflect the extreme complexity of river situations.

196. NEILL, C.R.
1973: Observations on River Channel Processes in Alberta; Proceedings of the 9th Canadian Hydrology Symposium on Fluvial Processes and Sedimentation University of Alberta, Edmonton, May 8-9, p. 325-338.

ABSTRACT:

This report summarizes selected findings from field studies on river channel processes and sedimentation conducted by the Research Council of Alberta and cooperating agencies between 1962 and 1972.

197. NEILL, C.R.
1976: Scour Holes in a Wandering Gravel River; Proceedings of the Symposium on Inland Waterways for Navigation, Flood Control and Water Diversions: 3rd Annual Symposium of the Waterways, Harbors and Coastal Engineering Division, American Society of Civil Engineers, p. 1301-1317.

ABSTRACT:

The paper describes a 110-km length of the Athabasca River in Central Alberta, characterized by great variability in channel shape and by a series of deep scour holes were the river turns abruptly against the valley walls. The geology, hydrology and hydraulic geometry of the river are summarized. Dimensions and characteristics of the scour holes are summarized and analyzed in relation to empirical methods of estimating maximum scour depths for engineering purposes.

198. NEILL, C.R., BRAY, D.I., SCHOUTEN, M.F. and CARD, J.R.
1970: Selected Characteristics of Streamflow in Alberta; River Engineering and Surface Hydrology Report 70-1, Research Council of Alberta and Water Resources Division, Alberta Department of Agriculture, 55 p.

ABSTRACT:

The report presents, by means of tables, maps and charts with brief commentary, statistics on streamflow derived from approximately sixty hydrometric gauging stations distributed throughout Alberta. The two principal sections of the report cover mean flows and their variability, and high and low flows and their variability. Introductory sections refer briefly to the history and methods of streamflow measurement in Alberta, to the influence of hydraulic engineering works on streamflow, to ice conditions, and to sediment transport. Appendices list sources of streamflow data and relevant previous reports and publications.

199. NEILL, C.R., EVANS, B.J. and LIPSETT, A.W.
1981: Circulation of Water and Sediment in the Athabasca Delta Area; Alberta Oil Sands Environmental Research Program Report 123, Project WS 3.3.1, October 1981, 116 p.

ABSTRACT:

The objective of the study was to describe how water and sediment from the Athabasca River are distributed through the delta system and how they circulate and mix in Lake Athabasca and flow through to the Slave River, with a view to understanding the pathways and destinations of contaminants that might reach the Athabasca River. Study components included literature reviews, remote sensing interpretations, field investigations and mathematical analyses. The project was viewed as a first stage study to sketch the essentials of the system and to outline needs and methodologies for a better definition.

General literature reviews cover briefly the hydrology of lakes, the mechanics of circulation and mixing in lakes and delta processes, with particular attention to circulation and mixing. The hydrology of principal lakes and channels in the study area is summarized using mainly information from past studies.

A series of selected satellite images and high-level aerial photographs taken between 1973 and 1978 is analyzed qualitatively to yield information on circulation and mixing. Limited previous water quality information is analyzed to supplement the remote sensing information.

Three field investigations were conducted in September 1979, March 1980 and June 1980. Data collected included water depths, current velocities, water quality parameters, and sediment concentrations. A special study of dispersive mixing was conducted during the June 1980 investigation. Efforts to obtain concurrent satellite data were unsuccessful, but field data have been compared against satellite data from an overpass about 9 days later.

Secondary studies reported included calculations of jet characteristics from delta distributary inflows, estimates of the zone of influence of lake outflows, and a consideration of the potential for mathematical and physical modelling of the system.

200. NEILL, C.R. and GALAY, V.J.
1966: Systematic Evaluation of River Regime; Proceedings of the Water Resources Engineering Conference, American Society of Civil Engineers, May 16-20, 1966, Denver, Colorado, 32 p.

ABSTRACT:

It is proposed that river regime be described by means of a standard set of key data, embracing geographic features, hydrologic and hydraulic data, materials and sediment, and channel processes. Methods of measuring and analyzing basic data in order to develop a set of key data are reviewed, with extensive references. A sample set of key data is presented for a 40-mile stretch of the Lower Red Deer River in the Province of Alberta. Regime changes that might result from engineering projects or land-use changes are discussed briefly, with reference to the same length of river.

201. NEILL, C.R. and MOLLARD, J.D.
1980: Examples of Erosion and Sedimentation Along Some Northern Canadian River; Proceeding of the International Symposium on River Sedimentation, Chinese Hydraulic Engineering Society, Beijing, China, Vol. 1, p. 565-600.

ABSTRACT:

This paper provides a presentation of the factors affecting erosion and sedimentation in northern rivers. It also describes fluvial features found in northern rivers. The authors also discuss engineering problems encountered at river crossings.

202. NEILL, C.R. and MOLLARD, J.D.
1982: Erosional Processes and Sediment Yield in the Upper Oldman River Basin, Alberta, Canada; Proceedings of the Exeter Symposium on Recent Developments in the Explanation and Prediction of Erosion and Sediment Yield. July 1982, IAHS Publication No. 137, p. 183-191.

ABSTRACT:

The upper Oldman basin descends eastward from the Continental Divide of the Rocky Mountains in southwest Alberta. Its 4000 km^2 area can be divided into Mountains, Foothills and High Plains. The paper discussion its sediment yield and the associated erosional processes. Suspended sediment yield averages 70 t km^{-2} $year^{-1}$, but varies greatly from year to year. This compares with a range of 20-100 elsewhere in Alberta and 0-350 in Canada generally. Principal erosional features identified include stream channel instability, ravine erosion, grassland gullying, wind erosion, and gravity-induced mass movements. An assessment of information obtained from airphoto interpretation and field reconnaissance indicates that erosional features are generally local in extent and are not creating widespread distress, that most present erosion is associated with streams and rivers, and that a substantial part of this is of natural geologic origin. The main source of main-made erosion appears to arise from public roads and associated interference with natural drainage. A potential for accelerated erosion appears to exist on grazing lands on substantial slopes. In the forest areas, erosion is minor compared to that in agricultural areas.

203. NEWBURY, R.W.
1968: The Nelson River: A Study of Subarctic River Processes; Ph.D. Thesis, John Hopkins University, Baltimore, Maryland, 318 p.

ABSTRACT:

The ice destruction period on the Nelson River occurs in May and early June. The major portion of the ice cover melts in place as the river is subdivided by a series of ice barriers, in some cases over 40 feet thick, that form during the winter through rapids zones. The rate of melting and accumulation of ice pans above barriers is subject to the heat budget and stability analyses developed for ice cover formation processes with suitable adjustments for surface conditions and the ice structure.

The principal effects of ice phenomena in the Nelson channel were found to be: (1) an annual cycle of bed erosion and infilling occurred where unconsolidated material was present in zones of ice accumulation, (2) bank and bed material of a size greater than that corresponding to the hydraulics competency of the river were striated and shifted downstream in local zones of ice cover movement, (3) a vegetation trim-line was developed along the channel boundaries corresponding to the maximum ice level, and (4) local sections of terraces and braiding were developed by flow shifts in rapids zones during the annual period of ice accumulation.

204. NEWBURY, R.W., BEATTY, K.G. and McCULLOUGH, G.K.
1978: Initial Shoreline Erosion in a Permafrost Affected Reservoir, Southern Indian Lake, Canada; Proceedings of the 3rd International Conference on Permafrost, 10-13 July, 1978, Edmonton, Alberta, p. 833-839.

ABSTRACT:

Field survey of eroding shorelines in permafrost affected fine-grained materials indicate that during the initial impoundment of a lake basin, deep erosion niches are formed at and immediately below the water's surface. Eroded volumes correlate well with erosive wave energies exerted on the shorelines but appear to be lower than the volumes anticipated in more southern reservoirs, particularly in the western USSR. The lower erosion rates are partially accounted for by the initial phases of impoundment distributing wave energies over a range of shoreline, the formation of a protective matte of forest debris on the foreshore, and the limiting of erosive capabilities by the rate of thawing of frozen materials under high wave energy conditions.

205. NEWBURY, R.W. and McCULLOUGH, G.K.
1984: Shoreline Erosion and Restabilization in the Southern Indian Lake Reservoir; Canadian Journal of Fisheries and Aquatic Sciences, Vol. 41, No. 4, p. 558-565.

ABSTRACT:

Prior to a 3-m impoundment in 1976, bedrock comprised 76% of the shoreline of Southern Indian Lake in northern Manitoba. This was reduced to only 14% of the shoreline as the water level rose above the wave-washed zone and flooded into the predominantly fine-grained, frozen overburden materials. Twenty monitoring sites were surveyed annually to determine rates of permafrost melting and solifluction and shoreline rosion. The sequence of shoreline erosion in permafrost materials was found to be cyclic, consisting of melting and undercutting of the backshore zone, massive faulting of the overhanging shoreline, and removal of the melting and fractured debris. Rates of shoreline erosion varied widely, depending on the exposure of the site to wave action and the composition of the backshore materials. At sites in fine-grained frozen silts and clays, representative of over three quarters of the postimpoundment shoreline, rates of retreat of up to $12\text{-m}\cdot\text{yr}^{-1}$ were observed. The total volume of shoreline materials removed varied from less than 1 to over 23 $\text{m}^3\cdot\text{m}$ shoreline $\text{length}^{-1}\cdot\text{yr}^{-1}$. Clearing of the forested backshore prior to flooding did not affect the erosion rates. The index of erosion based on the hindcast wave energy component perpendicular to the shoreline was 0.00035 $\text{m}^3\cdot\text{t-m wave energy}^{-1}$ (0.036 $\text{m}^3\cdot\text{MJ}^{-1}$). The minimum period of restabilization of the shoreline based on the volume of backshore materials that must be eroded before bedrock conditions are reestablished was estimated to be 35 yr for three quarters of the shoreline surrounding the lake.

206. NEWBURY, R.W., McCULLOUGH, G.K. and HECKY, R.E.
1984: The Southern Indian Lake Impoundment and Churchill River Diversion; Canadian Journal of Fisheries and Aquatic Sciences, Vol. 41, No. 4, p. 548-557.

ABSTRACT:

The 242 000-km^2 Churchill River basin extends across the northern half of Alberta, Saskatchewan, and Manitoba. In 1976, hydraulic control structures were completed to divert 75% of the natural river flow of 958 $\text{m}^3\cdot\text{s}^{-1}$ across the drainage divide separating the Churchill and Nelson river basins in northern Manitoba. The diversion flows follow 300 km of tributary valleys southward to the Nelson River channel where a 30-yr, 10 000 MW hydroelectric scheme is being developed. The diversion was accomplished by damming the northern outlet of Southern Indian Lake, a 1977-km^2 riverine lake on the Churchill channel (latitude 57°N, longitude 99°W). The dam caused a 3-m impoundment above the historical lake levels, which flooded 414 km^2 of the backshore zone. Permafrost, or permanently frozen ground, is widespread in the uplands surrounding the lake. As bedrock occurred on only 14% of the postimpoundment shoreline, severe erosion of the frozen backshore deposits is now underway. A long period of instability is anticipated on lake shorelines and in river valleys affected by the altered hydraulic regime. Although the whole-lake water exchange time was increased by only 41% by the impoundment, the circulation patterns and

exchange times in individual basins of the lake were changed dramatically when the Churchill waters were diverted at the southern end of the lake. The effects of the changing regimes on the aquatic habitats and fisheries of Southern Indian Lake have been investigated in pre- and post-impoundment studies undertaken by the Freshwater Institute of the Department of Fisheries and Oceans.

207. NIEMANN, K.O.
1979: Channel Patterns of the Upper Red Deer River, Alberta; Unpublished M.Sc. Thesis, Department of Geology, University of Alberta, 220 p.

ABSTRACT:

The Red Deer River, from the Rocky Mountain foothills across the high interior plains of western Alberta, reveals a variety of channel patterns. These encompass single-channel, relatively straight reaches through to multiple-channel, braided segments. This study attempts to specifically identify the various channel patterns and to place these in context with the factors which control their development.

Hydrographs for the gauging station situated near the mouth of Burnt Timber Creek are plotted for the period from 1974 to 1977. These plots show: (1) large variations in the discharge patterns exist on an annual basis and (2) large seasonal fluctuations in flow patterns occur. The seasonal variations reflect melting of the mountain snow pack in the headwaters and occur as floodwaves passing through the system. Yearly variations are determined by the size of the snow pack and the rate of melting.

The surficial geology and geomorphology of the Red Deer River Valley area are discussed in some detail. The present Red Deer River flows through a preglacial valley in which large quantities of coarse clastic material were deposited during deglaciation. These gravels have subsequently been reworked by the Red Deer River and distributed within the terraces and floodplain. The bank materials are, therefore, composed predominantly of gravel. There also occur a number of bedrock outcrops and along the banks in the study reach a minor amount of lacustrine silt and clay. The channel sediments show a well defined negative correlation of size against distance. A break occurs in the grain size trend at the foothills-plains boundary, with the foothills section having a greater rate of decrease in the size of the material than is found in the downstream portions. No significant relationship is shown between the sediment texture, degree of sorting and longitudinal profile slope.

Differentiation of channel patterns is accomplished through a width ratio (Wr) devised for this study. This ratio differentiates between single-channel and multiple-channel reaches. Comparison of the values obtained using the Wr values and the longitudinal profile indicates a weak negative relationship. Division of the longitudinal profile into six, distinct, secondary concavities reveals a stronger negative relationship between the channel slope and channel pattern. A positive relation between size and sorting of the channel sediment and the slope exist for most areas within these secondary concavities. This trend does not occur in two situations where major tributaries join the Red Deer River. The gentler sloped segments are therefore associated with higher Wr values. The occurrence of bedrock outcrops at the downstream limits of the concavities is also interpreted as being instrumental in increasing the Wr values. The outcrops act as controls which partially restrict flow furing the higher discharge events. This leads to the accentuated deposition of alluvium upstream from the controls, causing channel division and enhanced local bank erosion.

208. NORTHWEST HYDRAULIC CONSULTANTS LTD.
1976: Saskatchewan River Delta Study; Report Prepared for Ducks Unlimited, Winnipeg, 16 p. + Appendices.

SUMMARY:

1. The slow aggradation of the Saskatchewan Delta from Squaw Rapids to Cumberland Lake has been reversed to a degradation process due to the construction of Squaw Rapids Dam.

2. The Old Channel now receives less flow than it did in 1963, the completion data for Squaw Rapids Dam, because of degradation of the New Channel.

3. The flow necessary in the Saskatchewan River to initiate flow in the Old Channel is presently 9,500 cfs; the minimum flow will slowly increase in the future as degradation progresses. The Old Channel should, however, received adequate supplies of flow over the nest few years to regulate the marshes.

4. If the degradation progresses quickly then remedial measures may be necessary to increase flows in the Old Channel.

5. Several remedial measures for increasing flow to the Old Channel are discussed. Additional studies would be required to establish the feasibility of these measures and to evaluate their overall impact.

6. More detailed surveys at the Bifurcation and along the Old Channel should be carried out during low and high flows in order to better evaluate the degradation process and to better plan remedial works.

209. NORTHWEST HYDRAULIC CONSULTANTS LTD.
1978: Reservoir Sedimentation and River Degradation; Report Prepared for the Oldman River Study Management Committee, Edmonton, Alberta, 69 p.

ABSTRACT:

This report is one of 14 being prepared for the Oldman River study management committee as part of the Phase II studies. The paper reports on the Oldman basin reservoir sedimentation and degradation study, whose purpose was to investigate concerns about sedimentation of reservoirs and related problems connected with basin development. The principal objectives of the study were to determine (I) how long it would take for proposed reservoirs at the Brocket, Three Rivers or Castle sites to fill with sediment, and (II) how much the river channel downstream of these sites would be lowered by the cutting off of sediment supply. There are four potential reservoir sedimentation problems: 1) progressive loss of reservoir storage capacity through buildup of river-borne sediment, 2) channel degradation (lowering) downstream of the reservoir, 3) river bed aggradation (raising) upstream of the reservoir, and 4) wind and water erosion on steep reservoir shorelines. Of these four, the first is usually the most significant. Oldman basin is a moderate but noy heavy producer of sediment. Sediment yield determines how long it will take any reservoir to fill. Because a reservoir loses much of its usefulness long before it is full of sediment, it is more meaningful to speak of 'half-life' rather than life. The report states that the half-lives for Brocket, Three Rivers and Castle sites are estimated as 600,800, and 1100 years respectively assuming no change in land use. Channel bed degradation is unlikely to be a serious problem, because the river beds consist generally of gravel with a substantial proportion of sizeable stones. The channels will become paved with larger stones by the time the bed has degraded only a few feet.

210. NORTHWEST HYDRAULIC CONSULTANTS LTD.
1978: Reservoir Sedimentation and River Degradation: Supplementary Field Reconnaissance Report; Report Prepared the Oldman River Basin Study Management Committee, 12 page + Appendix.

ABSTRACT:

This report is supplementary to the report "Reservoir Sedimentation and River Degradation", by Northwest Hydraulic Consultants Ltd., dated March 1978. It covers helicopter reconnaissances of the Three River reservoir site and of the basins of the Crowsnest, Castle and Oldman Rivers above the site, conducted in May 1978.

Principal conclusions with respect to erosion and sedimentation are (i) that reservoir shoreline instability requires further investigation at the Three Rivers site, although it is unlikely to reduce reservoir capacity substantially; and (ii) that sediment loads in the Oldman River at Brocket are mainly derived from the non-forested parts of the basin where there are extensive depositions of fine-grained glacio-lacustrine soils. Geological valley widening processes along the main rivers are probably the principal source, but accelerated erosion in grazing and cultivated land is also a factor.

211. NORTHWEST HYDRAULIC CONSULTANTS LTD.
1979: Regime of Mackenzie River at Normal Wells in Relation to Artificial Island Scheme; Report Prepared for Esso Ressources Canada Ltd., 32 p.

ABSTRACT:

The report analyzes the morphologic characteristics and hydraulic geometry of the Mackenzie River in the vicinity of Norman Wells. The river has formed geologically by downcutting into glacial lake deposits, and flows generally in a bed of sandy alluvium overlying clay. In comparison with stable alluvial channels carrying similar discharges, it is relatively wide and shallow. Under high flow conditions the river can transport sand and gravel up to about 10 mm in size as bedload, and it carries a substantial load of silt and clay in suspension. Rates of change in the locations of the major banks and islands are generally very slow. Changes in major sand bars are more rapid, although slow compared to many large alluvial rivers. The influence of ice conditions on channel geometry and bed topography is difficult to define with assurance on the basis of available information.

The main effects of the proposed artificial islands on channel geometry are expected to be a minor amount of local channel deepening (1 to 2 m), and possibly some erosion on the Norman Wells side of Goose Island. It is considered possible that the islands may occasionally result in ice jamming and somewhat higher break-up water levels immediately upstream, but it is not considered possible that effects could be experienced as far upstream as Fort Norman.

212. NORTHWEST HYDRAULIC CONSULTANTS LTD.
1980: South Saskatchewan River Sedimentation Studies-degradation; Report Prepared for Saskatchewan Environment and Environment Canada, Edmonton, 37 p. + Figures.

ABSTRACT:

The construction of the Gardiner Dam has resulted in the trapping of substantial sediment loads within the reservoir which has resulted in some degradation of the river bed near the dam. Analysis of cross-section data and sediment data collected since the closure of the dam indicates that the average bed level has dropped 2 metres (6.5 ft) just below the dam and that the bed has started to armour (become coarser). The median size of the bed material within the active flow channel has changed from 0.38 mm to about 4.0 mm. The degradation has progressed approximately 8 km (5 miles) below the dam. The pattern of the river channel has not altered significantly and the river has become more stable since the operation of the dam, especially in the lower reach near Pike Lake.

Computations, using empirical relationships, show that ultimate degradation may be about 7.0 metres (23 ft) if further armouring of the bed takes place. More detailed computations using the HEC-6 computer model indicates that, by the year 2000, total degradation may be about 4.2 metres (13.8 ft). The computer model also verifies that a high release could result in a slight increase in degradation.

The survey program carried on over the previous 15 years was adequate to study the degradation process. The future program should, however, be modified with more cross-sections to be taken near the dam, but on a less frequent basis that the existing program.

213. NORTHWEST HYDRAULIC CONSULTANTS LTD.
1984: Sedimentation Assessment of Forty Mile Creek near TransCanada Highway, Banff National Park; Report Prepared for Public Works Canada, Western Region, Edmonton, 8 p.

ABSTRACT:

Maintenance problems associated with erosion and sedimentation of Forty Mile Creek near the TransCanada Highway crossing in Banff are described. The hydrologic, morphologic and hydraulic characteristics of the creek over a length of about 2 km are described briefly and illustrated. Recommendations and details are presented for stabilization work to reduce maintenance, involving minor local realignment of the channel and protection of the lower banks with riprap derived from rock cuts in the highway twinning program.

Appendices contain comments on a maintenance problem in Healy Creek, and illustrations of a few other creeks viewed at the time of the field inspection.

214. NORTHWEST HYDRAULIC CONSULTANTS LTD.
1984: Hydrological and Sedimentation Assessments for the Proposed Land Use Management Program, Buffalo Bay - Horse Lakes Delta Complex, Stage II, Phase II, Vol. 1; Report Prepared for the Planning Division, Alberta Environment, 40 p. + Appendices.

SUMMARY:

The Buffalo Bay - Horse Lakes delta complex is located at the west end of Lesser Slave Lake. Channelizing and diking at the lower ends of the three primary rivers feeding this delta (East Prairie River, West Prairie River, South Hearth River) during the 1960's and 1970's produced dramatic changes in their flow pattern and sedimentation regimes. Areas within the delta are presently being utilized for agricultural, wildlife and fisheries purposes. The future behaviour of these river channels in relation to the various land uses, and the possible enhancement in productivity of these land uses, has been the subject of a special study by Alberta Environment.

Stage I of the study was completed during 1983 and assessed the hydrotechnical aspects of three conceptual land use management plans. It was concluded that a management plan could be implemented and operated successfully, given the water level and sedimentation controls contemplated.

Stage II of the study commenced in early 1984 to study in detail a single land use management plan, as outlined in Figure 1. Study activities were separated into two phases. Phase I involved development of two computer models: (1) flow routing model; (2) sediment transport routing simulation model. Phase II involved use of these models and assessment of results. This report summarizes the Phase II findings.

Table 1 lists the elements requiring hydrotechnical assessment in evaluating the proposed land use management plan, while Figure 2 outlines their arrangement schematically. Generally, four water control structures are required, each of which would involve a sharp-crested weir design. The selection of weir widths and heights, in combination with incoming discharges and Lesser Slave Lake levels, produced a large number of possible scenarios. The structure geometry for the recommended scenario is summarized in Table 8.

Figure 3 provides a set of bed and water surface profiles for the primary channels within the study area, as well as weir locations and heights, are predicted sedimentation rates along these channels. Figure 8 provides profile plots for the East Prairie and West Prairie rivers that extend far upstream into their respective basins; the modelled reach is shown in relation to the longer profiles.

Sediment transport modelling of the recommended scenario showed the following:

1. Only sand is deposited in the river channels entering both silt traps; approximately 11 and 50 percent of the total sand load is deposited by the East Prairie River and South Heart River, respectively.

2. The average annual aggradation rate, based on a 21-year modelling period, is 0.2 ft/yr and 0.4 ft/yr for the East Prairie River and South Heart River, respectively.

3. In all cases, the remaining sand and essentially all of the silt is deposited in each of the silt traps; the clay load passes completely through the traps and is carried into Lesser Slave Lake.

4. It is estimated that the proposed East Prairie River silt trap would have a life of about 25 years, so to achieve a 30-year life it is recommended that the silt trap area be increased from 5.4 km^2 to 6.4 km^2. The proposed South Heart River silt trap would have a life in excess of 30 years.

Over the years, it will likely be necessary to construct internal dikes and to breach levees along channels within each silt trap in order to force sediment deposition to occur throughout the silt trap areas.

As well, it will be necessary through aggrading reaches, to main a minimum capacity in both channels by intermittent excavation. As a guide, it has been recommended that the channels be maintained to the year-10 bed profiles shown in Figure 3. The annual cost of maintaining these channels should be based on a need to annually excavate 60,000 tons/year and 170,000 tons/year of sand from the East Prairie River and South Heart River channels, respectively.

The problem of debris was addressed and it was concluded that the silt traps would also behave as debris traps, provided adequate channel depths are maintained upstream. It is recommended that debris catchers be installed immediately upstream of each weir.

215. NORTHWEST HYDRAULIC CONSULTANTS LTD.
1984: East Prairie River, West Prairie River Sediment Transport Regimes at Highway 2, Potential for Future Change, Stage II, Phase II, Vol. 2; Report Prepared for the Planning Division, Alberta Environment, 32 p. + Appendices.

SUMMARY:

This report presents the findings of two special studies that were conducted as part of Stage II, Phase II, in the assessment of a proposed land use management plan for the Buffalo Bay - Horse Lakes delta complex.

The first special study was for the purpose of resolving the question of what might be the ultimate channel regimes of the East Prairie and West Prairie rivers, with special consideration given as to what their long term sediment loads might be at Highway 2. Northwest Hydraulic Consultants Ltd. had the responsibility of completing this study.

The second special study addressed the question of whether the high floods of the 1970's were characteristic of what could be expected in the next few decades. This study was conducted in-house by Alberta Environment, the report of which is presented as Appendix D, herein.

In the first study, it was resolved that the primary factor influencing sediment loads at Highway 2 on both rivers is the impact of man-made works; specifically the channelization of these rivers downstream of Highway 2. These works have resulted in bed degradation and enhanced bank erosion upstream of the highway during the last 10 to 20 years.

For the East Prairie River, of the 861,000 tonnes/year passing Highway 2 (on average), it is estimated that 370,000 tonnes/ year are contributed from the reach of river presently experiencing bed degradation and enhanced bank erosion (extends to about 10 km upstream of highway). Of this quantity, 35 percent is attributed to bed degradation and 65 percent to bank erosion.

For the West Prairie River, of the 391,000 tonnes/year passing Highway 2 (on average), it is estimated that 158,000 tonnes/ year are contributed from the reach of river presently experiencing bed degradation and enhanced bank erosion (also extends to about 10 km upstream of highway). Of this quantity, 35 percent is attributed to bed degradation and 65 percent to bank erosion.

In the second special study, based on assessments of flood peaks and storm events in the East Prairie River basin, it was concluded that a decade of relatively high flood peaks such as occurred during the 1970's probably occurs once every three decades, on average. Thus, use of flow data from both the East Prairie and West Prairie rivers for the period from the 1960's through to 1983 for estimating sediment transport, is recommended as providing a good range of flow situations for design of the proposed silt trap system in the Buffalo Bay - Horse Lakes delta complex.

Geotechnical information was collected along both rivers upstream of Highway 2. The objective was to determine whether the degradation process has the potential of being ultimately arrested by some highly erosion-resistant material underlying the present channels. Based on this information it was concluded that as the channels continue to degrade, they will eventually encounter till that is composed of very inerodable clay. The predicted 'ultimate' bed slopes for both rivers are shown in Figure 3. These profiles have been based on estimated regime channel slopes, assuming that some further aggradation can be tolerated downstream of Highway 2 before channel capacities have to be maintained.

It is expected that at least 15 years will be required for the East Prairie River to attain a stabilized bed profile upstream of the highway; for the West Prairie River it appears that this will be achieved in about 10 years.

The quantities of sediment derived from bank erosion in the degrading reaches are not expected to change from present rates for several decades. It was established that small shifts in the meander pattern produced relatively large amounts of sediment and this process will not be diminishing unless extensive bank protection measures are undertaken.

Although the long term average annual sediment loads passing Highway 2 in both the East Prairie River and West Prairie River might be expected to decrease 10 to 15 percent once the 'ultimate' bed profiles are achieved, it is recommended that the existing discharge-sediment transport rate relationships not be adjusted accordingly in the analysis of silt trap life.

216. NORTHWEST HYDRAULIC CONSULTANTS LTD.
1985: Buffalo Bay - Horse Lakes Management Program, Stage II - Hydrotechnical Analysis, Sediment Transport Routing Simulation Model, User's Manual; Report Prepared for the Planning Division, Alberta Environment.

217. NORTHWEST HYDRAULIC CONSULTANTS LTD.
1985: Assessment of Sediment Issues and Survey Program in the Prairie Provinces; Report Prepared for Sediment Survey Section, Water Resources Branch, Environment Canada, 111 p. + 2 Appendices.

ABSTRACT:

The study is one of a series commissioned in 1984 by the Sediment Survey Section of Water Resources Branch, Environment Canada. It was designed to provide a better understanding of the role and importance of streamborne sediment in the Prairie Provinces and to make recommendations for the future direction of the Sediment Survey program.

218. NORTHWEST HYDRAULIC CONSULTANTS LTD. and J.D. MOLLARD AND ASSOCIATES and W.H. POLIQUIN
1980: Erosional Features and Processes in the Upper Oldman River Basin; Report Prepared for the Planning Division, Alberta Environment, Lethbridge, 3 p.

ABSTRACT:

The purpose of the study was to map and describe areas exposed to erosion from natural or man-made causes, focusing on the river valleys of the Oldman River, Crowsnest River and Castle River and their principal tributaries above the junction of the Oldman and Castle Rivers. The study involved analysis of documents, maps and aerial photographs, inspection and photography of the basin from the air and on the ground, and consideration of physiographic, geological and hydrological factors.

An assessment of the information compiled indicates that erosional features are generally local in extent and are not creating widespread distress, that most present erosion is associated with streams and rivers, and that a large part of this is of natural geologic origin. The main source of man-made erosion appears to arise from public roads and the associated interference with natural drainage systems. A potential for accelerated erosion appears to exist on grazing lands or substantial slopes. In the forest areas, erosion is minor compared to that in agricultural areas.

219. NORTHWEST HYDRAULIC CONSULTANTS LTD. and UNDERWOOD McLELLAN LTD.
1983: St. Mary Main Canal Rehabilitation Guidelines, Volume VIII, Sediment Balance; Report Prepared for the Design and Construction Division, Alberta Environment and the St. Mary River Irrigation District, 14 p. + Appendices.

SUMMARY:

Introduction

This report discusses sediment problems associated with the St. Mary Main Canal. On the basis of erosion and deposition surveys and limited sediment sampling, an approximate sediment balance is developed for the canal indicating quantities of sediment supplied from various sources and the allocation of sediment outflows between laterals and reservoirs.

Sediment Supply and Balance

Suspended sediment transported by the main canal arises mainly from bank erosion, with secondary contributions from bed erosion, land surface runoff and wind erosion of fields. The main input is between Stafford and Sauder Reservoirs where the estimated historic sediment supply averages approximately 80,000 tons/yr, of which roughly half outflows via laterals and half deposits in Sauder Reservoir. Trends of sediment increase or decrease with respect to time are unknown.

Sediment Distribution

Sediment loads and concentrations increase along the canal as inputs accumulate and canal flows diminish. Highest concentrations occur upstream of Sauder Reservoir, which has accumulated some 900 acre-ft of sediment, approximately 20 percent of the original live storage volume.*

Effects of Rehabilitation

The proposed rehabilitation program involving continuous bank protection by gravel should reduce sediment inputs to one half or less of past quantities.

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* Sauder Reservoir was extended in 1981. Reference is to the original reservoir only.

220. ONGLEY, E.D.

1982: Influence of Season, Source and Distance on Physical and Chemical Properties of Suspended Sediment; Proceedings of the Symposium on Recent Developments in the Explanation and Prediction of Erosion and Sediment Yield, Exeter, July 1982, IASH Publication No. 137, p. 371-383.

ABSTRACT:

Understanding of source, pathways and fate of suspended sediment-associated nutrients and contaminants is now recognized as an important element of water resource management. The geochemically active fraction (<62 μm) of the suspended sediment

load concentrates nutrients, metals and organic contaminants by several orders of magnitude above ambient water concentrations. Because this sediment fraction tends to be flow dependent, is not depth dependent nor adequately characterized by bottom sediments, collection of suspended sediment for geochemical purposes requires new sampling strategies. Mineralogy and major element analysis together with systematic seasonal changes in physical characteristics of suspended matter can assist in identifying seasonally variant source areas. Changes in sediment chemistry during downstream transport reflect a suite of biogeochemical processes which should be explicitly considered when assessing the environmental relevance of sediment quality.

221. ONGLEY, E.D.
1984: Nutrient and Contaminant Pathways in Prairie Rivers; Interim Report, Saskatchewan River Basin Study, NWRI Study Plan No. 183, 19 p.

ABSTRACT:

This report reviews the background and progress of the Saskatchewan River study. It provides a synthesis of data collected during the 1983 field program. This interim report summarizes the majority of work associated with NWRI Study Plan No. 183 which is supported by A-Base and TCMP funds. Data reproduced here are those for which NWRI-Winnipeg has principal responsibility. Data reported by co-researchers in NWRI-ECD and EPS are reported elsewhere and will be summarized in a final project report.

222. ONGLEY, E.D. and BLACHFORD, D.P.
1982: Application of Continuous Flow Centrifugation to Contaminant Analysis of Suspended Sediment in Fluvial Systems; Environmental Technology Letters, Vol. 3, p. 219-228.

ABSTRACT:

Suitability of continuous-flow centrifugation for bulk recovery of suspended sediment for biogeochemical purposes is reviewed. Centrifuge recovery characteristics and efficiencies in a variety of rivers and for different regimes are presented. The observed distribution of organochlorine residues amongst water, aquatic plants and suspended sediments demonstrate the necessity for standardized bulk collection protocol for suspended sediment.

223. ONGLEY, E.D. and BLACHFORD, D.P.
1982: Nutrient and Contaminant Pathways in the Bow and Oldman Rivers, Alberta 1980-1981; Report to the Toxic Contamination and Management Program, Environment Canada, Kingston, 107 p.

ABSTRACT:

The Bow and Oldman Rivers with their tributaries, together with the Red Deer, are the principal river systems of Southern Alberta.

They merge to form the South Saskatchewan River in south-central Alberta. The South Saskatchewan River system traverses a variety of climatic regimes. The basin hydrography is shaped by the alpine sources of the Bow and Oldman Rivers and, in particularly, by various glacial sources of the Bow. The Bow and Oldman each have one major urban point source -- Calgary and Lethbridge respectively. The effects of diffuse sources are not well known upon major rivers in this region. Large scale irrigation in Alberta is one potential diffuse source of sediments, nutrients, heavy metals and agricultural chemicals. Some of these are addressed in this study. Over the past decade public perception of water quality of the Bow River has been influenced by the dense growths of rooted macrophytes which thrive below the Calgary sewage outfalls and which in 1979 extended downstream to the confluence of the Bow and Oldman Rivers. These form nuisance rafts of organic debris which clog water intakes as far downstream as Medicine Hat. The role of aquatic weeds in uptake and storage of phosphorus and contaminants is addressed here. This study focusses primarily on the reach of river extending downstream from Calgary on the Bow, and from Lethbridge on the Oldman to their confluence at 'Grand Forks' (Bow Island), a river distance of 339 km and 177 km respectively. Each reach commences with a major point source, then flows for long distances across increasingly arid conditions where potential anthropogenic impact is restricted to water diversion for irrigation purposes, irrigation return-flows and the occasional riparian feedlot. Water and suspended sediment samples were collected at thirteen sites (eight on the Bow and five on the Oldman) during the early summer ('80), summer ('80), fall ('80) and spring ('81) discharge regimes. Samples were collected systematically downstream to reflect time-of-travel (hydrologic synoptic sampling). Aquatic plants were collected during the summer and fall of 1980. A selection of irrigation returns flows was sampled every two to three weeks for much of the irrigation season (June to Sept., 1980). The major scientific findings and management implications are summarized.

224. ONGLEY, E.D. and BLACHFORD, D.P.
1984: Tributary Effects on Mainstream Suspended Sediment Chemistry; Water Pollution Research Journal, Vol. 19, No. 1, p. 37-45.

ABSTRACT:

The relative impact of tributaries on suspended sediment (organic + mineral particulate matter) chemistry below a confluence can be evaluated using suspended sediment concentration and particulate elemental concentrations from each of the two inputs and from a mixed sample below the confluence. Although suspended sediment chemistry below a confluence is a product of mixing of mainstream and tributary inputs, variability in chemical data in field samples is caused by inhomogeneities in the sampled medium and by limitations inherent to sampling and analytical procedures. This study assesses data variability typical of a Canadian Plains river during a period of substantial discharge, large suspended sediment transport, and turbulent mixing conditions. Using particulate

elemental concentration from each of the two streams contributing to a confluence, element concentration below the confluence is predicted. Variance between observed and predicted element concentrations permits an assessment of analytical error for each element. We demonstrate that substantial variations in input chemistry cause small and predictable changes in downstream suspended sediment chemistry.

225. OOSTERVELD, M. and McMULLIN, R.W.
1979: Inflow-outflow of Nutrients and Sediment for a Flood- and a Sprinkler-irrigated Watershed in Alberta; Canadian Journal of Soil Sciences, Vol. 59, No. 2, p. 177-182.

ABSTRACT:

Nutrients and sediment were monitored in irrigation supply and in the drainage waters associated with a flood and a sprinkler irrigated watershed. NO3-N concentrations in runoff from the flood irrigated farm ranged from 1.38 mg per liter in 1975 to 1.60 mg per liter in 1976. Rapid transformations in a drain channel reduced these by 90% after the water travelled 2.5 km in the drain. P concentrations were also reduced in the runoff water in the drain channel. At the basin outlets, the concentrations were only marginally higher than in the supply water. NO3-n discharged at the basin output represented 0.5 kg per ha per yr for flood-irrigated land and 0.7 kg per ha per yr for sprinkler irrigated land. Corresponding total P exports computed from the persulfate digestion method were 0.2 and 0.3 kg per ha per yr. Exports represented about 1.6% of fertilizer applied N and 1.0% of the applied P in each basin. Sprinkler irrigation resulted in a net inflow of suspended sediment whereas on flood irrigation, sediment inflow and outflow were about equal. Total P concentrations by the perchloric digestion method were about twice as high as those determined by the persulfate method, confirming that the persulfate method does not remove all the P absorbed to sediment.

226. OSCARSON, D.W., HUANG, P.M. and LIAW, W.K.
1980: The Oxidation of Arsenite by Aquatic Sediments; Journal of Environmental Quality, Vol. 9, No. 4, p. 700-703.

ABSTRACT:

Sediments from five lakes in southern Saskatchewan, Canada, oxidize As(III) (arsenite) to AS(V) (arsenate). The oxidation is not affected by flushing N2 or air through the sediment suspensions, nor does the addition of HgCl2 to the system eliminate the conversion of As(III) to As(V). The oxidation is an abiotic process with microorganisms playing a relatively minor role in this system. Because As(III) is more toxic and sorbed to a lesser extent by sediments than As(V), the suspended and bottom sediments may potentially alleviate the toxicity of As(III) through abiotic oxidation in aquatic environments.

227. OSHOWAY, R.
1982: Dauphin Lake Sedimentation Study; Internal Report, Manitoba Department of Natural Resources, Water Resources Branch, 21 p. + Appendices.

ABSTRACT:

Sediment inflow to Dauphin Lake from tributary streams was compiled for a 31 year period and found to be an average of 550,000 tons per year or about 420 acre-feet per year. Approximately 99 percent of this sediment is trapped in the Lake.

The sediment reduced the volume of the lake by 4.3% per 100 years and reduces the average depth of the lake of 7.8 feet by 4.1 inches per 100 years. At these rates the lake would be filled completely in about 2,300 years.

Analysis of river deltas indicates that only a small part of the sediment is deposited in the deltas. Most of the sediment is widely distributed over the lake bottom, particularly in the southern half of the lake.

228. OSHOWAY, R. and PENNER, F.
1981: Sedimentation in the Lake of the Prairies; Internal Report, Manitoba Department of Natural Resources, Water Resources Branch, Winnipeg, 12 p.

ABSTRACT:

This report presents a comparison of the data collected during the 1973 and 1978 morphological surveys of Lake of the Prairies using the HYDAC-100 system and suspended sediment data collected in 1981 at the inflow and outflow of the lake and shoreline erosion. Results show that:

1. The volumes of deposition derived from the HYDAC-100 surveys of about 1.6 x $10^6 m^3$ per year or 0.3% of the reservoir full supply volume per year are not reliable.

2. The quantity of suspended sediment contributed by streamflow and deposited in the reservoir is approximately 7,948 tonnes per year, 7,948 m^3 per year or 0.002% of the reservoir full supply level per year and is considered to be negligible.

3. The quantity of sediment derived from shoreline erosion is approximately 121,000 m^3 of bank volume per year, 182,000 tonnes per year, 182,000 m^3 of deposited volume per year or 0.04% of the reservoir full supply level per year and is considered to be of no practical significance.

4. Shoreline erosion occurs above the summer target operating level and thus increases the flood storage volume above this level but decreases the water conservation volume below this level.

5. The probable volumes of deposition are so small in terms of the reservoir capacity that no further studies of deposition are warranted.

6. Depending on the nature and degree of shoreline development, some monitoring of shoreline erosion may be warranted.

7. With a difference in calculated sediment volumes in excess of five million cubic metres between the Hydac-100 results and the suspended sediment and shoreline erosion results, the Water Survey of Canada may wish to re-survey some or all of the sectors to resolve the difference. In this case the horizontal control points for the Hydac-100 surveys should be carefully referenced and permanently marked for future surveys.

229. ØSTREM, G., BRIDGE, C.W. and RANNIE, W.F.
1967: Glacio-Hydrology, Discharge and Sediment Transport in the Decade Glacier Area, Baffin Island, N.W.T.; Geografiska Annaler, Vol. 49, Series A, p. 268-282.

ABSTRACT:

Mass balance studies were initiated in 1965 on the Decade Glacier near the head of Inugsuin Fiord on the eastern coast of Baffin Island. The investigation is a part of Canada's contribution to the International Hydrological Decade Program. Detailed measurements of accumulation and ablation gave average figures of 25 cm and 21 cm respectively and thus the 1965 budget was slightly positive. Discharge measurements showed a close connection between rainfall and high discharge peaks in the glacier stream, whereas periods of high air temperature gave only small rise in river discharge. A similar pattern was obtained for the Inugsuin River which drains an almost glacier-free area of 125 km^2. The bulk of the annual run-off is assumed to pass the gauging station during the summer field season, and a rough calculation based upon a provisional rating curve indicated a yearly precipitation in the order of 430 mm in the catchment area of Inugsiun River.

The sediment load was measured 2-3 times daily in the Decade River, draining 12.8 km^2 of which 8.7 km^2 (68%) is glacier-covered. In addition, a more detailed study was made once a week by sampling every 3 hours in a 24-hours period. The sediment transport showed high variations, from a few kg/day to a maximum of 1183 x 10^3 kg/day; the latter figure was observed on July 29 and it proved to be almost 60% of the total amount of suspended inorganic material moved by the river during the whole observation period.

230. OUTHET, D.N.
1974: Bank Erosion in the Southern Mackenzie River Delta, Northwest Territories, Canada; Unpublished M.Sc. Thesis, Department of Geography, University of Alberta, Edmonton, 88 p.

ABSTRACT:

Analysis of 2-week time lapse photography in the field and from the air, along with other data collected in the field, indicates that in the southern Mackenzie River Delta, the shape of an eroding bank is positively correlated with the erosion process and the rate and character of erosion. Poor correlations between bank erosion and the following factors indicate the complexity of erosion processes: current velocity; channel orientation to the wind; ice content of the bank sediment; vegetation; roots; water temperature; and ice during break-up. Prediction of bank erosion cannot be made by measuring these factors. There are five different easily-distinguished bank shapes in the study area each with its own maximum and minimum erosion rates and manner of erosion. This information allows the short-term prediction of eroding bank behaviour on the basis of bank shapes and the production of a map showing the erosion rate category into which each bank fits. This map may be used in the planning of construction in the area to avoid rapidly eroding banks such as those that may erode up to 30 m/yr.

231. PARKER, G.
1978: Self-formed Straight Rivers with Equilibrium Banks and Mobile Bed. Part 1. The Sand-silt River; Journal of Fluid Mechanics, Vol. 89, Part 1, p. 109-125.

ABSTRACT:

Rivers and canals with perimeters composed of non-cohesive sand and silt have self-formed active beds and banks. They thus provide a most interesting fluid flow problem, for which one must determine the container as well as the flow. If bedload alone occurs across the perimeter of a wide channel, gravity will pull particles down the lateral slope of the banks; bank erosion is accomplished and the channel widens. In order to maintain equilibrium, this export of material from the banks must be countered by an import of sediment from the channel centre.

The mechanism postulated for this import is lateral diffusion of suspended sediment, which overloads the flow near the banks and causes deposition. The model is formulated analytically with the aid of a series of approximate but reasonable assumptions. Singular perturbation techniques are used to define the channel geometry and obtain rational regime relations for straight channels. A comparison with data lends credence to the model.

It is hoped that a first step has been made towards a more general treatment, which would include various complicating factors that are important features of natural rivers but are not essential to the maintenance of channel width. Among these factors are meandering, sediment sorting and seepage.

232. PARKER, G.
1978: Self-formed Straight Rivers with Equilibrium Banks and Mobite Bed Part 2. The Gravel River; Journal of Fluid Mechanics, Vol. 89, Part 1, p. 127-146.

ABSTRACT:

Rivers are capable of transporting their own bed material without altering their width. However, a naive extension of the threshold theory of canals in coarse alluvium to straight reaches of gravel rivers leads to the stable-channel paradox: transport of bed material is incompatible with a stable width. In this paper singular pertubation techniques are used to obtain a bed stress distribution which allows a mobile bed but immobile banks at bankfull or dominant discharge. This result is used to obtain regime relations for straight rivers with bed and banks composed of coarse gravel.

The analysis, although dependent on a series of approximate assumptions for Reynolds-stress closure and sediment transport, provides reasonable agreement with data.

233. PARKER, G. and ANDRES, D.
1976: Detrimental Effect of River Channelization; In: Rivers '76, Proceedings of the Symposium on Inland Waterways for Navigation, Flood Control and Water Diversions, 3rd Annual Symposium of the Waterways, Harbors and Coastal Engineering Division of the American Society of Civil Engineers, Aug. 10-12, 1976, Colorado State University, Fort Collins, Colorado, Vol. II, p. 1248-1266.

ABSTRACT:

The East and West Prairie Rivers in Alberta, Canada, drain the Swan Hills uplands and debouche upon a Lacustrine plain that once constituted part of the bed of Lesser Slave Lake. The streams naturally aggrade in their downstream reaches, and thus are prone to frequent flooding. Development of the flood plains has increased the sediment load and aggravated the flood problem in the cultivated plain.

Extensive reaches of both rivers were channelized and straightened between 1953 and 1971 in an attempt to provide flood relief. The morphologic consequences of the channelization became manifest in a relatively short time. The improved ability of the channels to handle floods is being destroyed in the lower channelized reaches by aggradation. In the upper reaches, as much as 15 feet of degradation was observed between 1964 and 1974. Incipient meandering is apparent in the lower reaches, and in the naturally meandering reaches above the channelized portion a combination of degradation and channel migration has destroyed some farmland.

Channel straightening is an engineering technique that has been used frequently, in recent years, when varying degrees of success. In this paper, an in-depth analysis of one specific case is presented as an evaluation of the technique. Furthermore, existing theories are applied in an attempt to see if the detrimental effects could have been predicted with some quantitative accuracy before the straightening had been undertaken. The question of possible alternatives to channel straightening is also addressed.

234. QUAZI, M.E. and BECKSTEAD, G.
1977: Sylvan Lake Regulation Study, Shoreline Erosy Study; Internal Report, Technical Services Division, Environmental Engineering Support Services, Alberta Department of the Environment, Edmonton, 68 p.

ABSTRACT:

A study of the shoreline processes on Sylvan Lake was conducted to determine the effects of water level regulation. This study provides historic data on shoreline erosion and ice damage. It also predicts the effects of water level regulation on shoreline erosion (or shoreline advance), and the effects of ice on the shoreline and shoreline structures. The wave climate (waves, winds, and wind setup) was developed from empirical equations utilizing field wind data from a nearby meteorological station. The design wind, wave and wind setup were determined to be 89 miles per hour, 2.4 feet, and 0.6 feet respectively. Historic rates of shoreline erosion could only be obtained from the responses of Sylvan Lake cottage owners to the shoreline questionnaire. They estimated the erosion rate to be 0.5 feet per year. The amount of shoreline adjustment due to the effect of lake level regulation was calculated at between 28 and 127 feet. Two models relating the rate of erosion to lake level and wave climate were used to determine the upper and lower time limits required for profile shifts of occur. This time should be between 48 and 240 years. Land loss computations due to erosion were also performed which showed that the present average loss is about 1.3 acres/year. Historic ice effects on shoreline and shoreline structures were assessed on the basis of field evidence and office studies of ice expansion factors, wind driven ice forces, up-slope ice travel distance and height of ice mound calculations. Maximum ice expansion and pile up distances were calculated to be 87 and 4.1 feet respectively. This data was then used to estimate the effect of regulation on the shoreline and shoreline structures from wave and ice processes.

Operating procedures for the outlet control structure which would mitigate the damages to the shoreline and shoreline structures from wave and ice action, were recommended.

235. RANNIE, W.F.
1968: Sediment Movement in Graburn Watershed Cypress Hills, Alberta; Unpublished M.Sc. Thesis, Queen's University, Kingston, 129 p.

ABSTRACT:

Graburn Watershed is representative of the watersheds along the northeastern margin of the Cypress Hills, Alberta. The movement of sediment was studied from the beginning of May to the end of August, 1967, in relation to the hydrologic regime, physical characteristics and the microclimate of the watershed.

Erosion by sheet and rill wash is inhibited by the topography and vegetation and the sediment load of Graburn Creek is derived primarily from gulley and channel erosion. Landsliding is a major process by which sediment moves toward the channel system. Quartzite cobbles from the Cypress Hills Formation armour most channel beds within the watershed, and bed material movement occurs only during infrequent high flows.

Severe snowmelt in mid-May, 1967, produced a flood with a recurrence interval of greater than 50 years. The sediment yield of Graburn Creek from May to August was 27,000- 47,600 tons; 17,600 tons were transported as suspended load, 7,800-28,300 tons as bedload, and 1,700 tons as dissolved load. More than 96% of this yield occurred during the peak snowmelt period from May 16 to May 21. Rainfall from June to August was unusually low and produced no significant transport of clastic sediment.

236. RASID, H.
1979: The Effects of Regime Regulation by the Gardiner Dam on Downstream Geomorphic Processes in the South Saskatchewan River; Canadian Geographer, Vol. 23, No. 2, p. 140-158.

ABSTRACT:

Under equilibrium conditions some hydraulic characteristics of a stream channel, such as depth, width, channelbed slope, and suspended load, are adjusted to the hydrologic regime of the stream. Therefore, it is postulated that if the regime of a river is regulated by constructing a dam across its channel, some short-term adjustments in the hydraulic characteristics of the river will begin immediately following the closure of the dam. This hypothesis has been tested empirically, using the example of the effect of regime regulation by the Gardiner Dam on the South Saskatchewan River.

The important variables which control stream channel morphology have been identified by Leopold and Woldman as discharge, amount of sediment load, size of load, channel width, channel depth, stream velocity, channel slope, and channel roughness. Based on the interrelations among these variables. Schumm has formulated a number of equations to forecast the expected morphologic readjustments of river channels in response to altered hydrologic regime. However, past experience has shown that such theoretical equations are not adequate, because it is extremely difficult to generalize about the probable changes to be expected on rivers of diverse characteristics. DeVries has therefore suggested that greater attention should be given to the actual rates of change in river channels. This paper uses an empirical approach of this type, through it is intended to demonstrate that the actual geomorphic changes in the South Saskatchewan River below the Gardiner Dam conform not only to empirical observations of changes at other dam sites but also to theoretical expectations.

A major problem in studying multivariate river channel changes induced by dams is that a long period is necessary for comparatively stable conditions to be recreated. Although rivers adjust rapidly in the geological sense to altered hydrologic regimes, complete adjustment may not occur during the lifetime of one individual. Nonetheless, significant changes in river morphology may be observable even within a few years of the completion of a dam, as this paper will demonstrate.

237. REEDER, S.W., HITCHON, B. and LEVINSON, A.A.
1972: Hydrogeochemistry of the Surface Waters of the Mackenzie River Drainage Basin, Canada - I. Factors Controlling Inorganic Composition; Geochimica et Cosmochimica Acta, Vol. 36, p. 825-865.

ABSTRACT:

The surface waters of the Mackenzie River drainage basin, Canada are virtually unpolluted. A suite of 101 surface waters was collected mainly during a three week period in the summer of 1969 and represents an instant in time during a period of average flow for most rivers in the basin. Twenty two major and minor inorganic chemical components are reported, together with physical properties and documented details of the area and proportion of rock types in the sub-basins. Q-mode factor analysis demonstrates that three factors account, essentially equally, for nearly 96 percent of the information among the samples. They represent the influence of solution of evaporites and associated carbonate rocks, the influence of weathering products of calcereous marine shales, and the influence of weathering products of igneous and metamorphic rocks and non-calcaerous shales. R-mode factor analysis shows that over 91 percent of the variance is accounted for by seven factors, summarized below:

Factor	Major (minor) loadings	Source
1	$Ca-Mg-Sr-HCO_3-(SO_4)$	Carbonate minerals and gypsum
2	K-B-(Na)	Illite
3	SiO_2	Bentonites and hot springs
4	PO_4 (organic)	Particulate organic matter
5	Fe-B-(Na)	Glauconite
6	Na-Cl	Halite
7	$U-SO_4$	Uranyl-sulphate complexes

The factor results confirm that the main control on the inorganic composition of these surface waters is exerted by the bedrock encountered by the water during its residence in the sub-basins.

The Mackenzie River, where it enters the delta, has contents of Li(<5 μg/l.), B(20 μg/l.) and F(0.09 mg/l.) which are close to suggested world average river composition, whereas the content of

U(0.05 μg/l.) is higher. Strontium (0.21 mg/l.) is about four times the suggested world average, due mainly to abundant fossiliferous carbonate rocks, whereas SiO_2 (3.5 mg/l.) is much less. The base metals Ni (<2 μg/l.), Cu(2 μg/l.) and Zn (1 μg/l.) are present at levels about one order of magnitude lower than suggested world averages but, due to the analytical techniques used, our values represent near true soluble ions whereas the world averages may include some metals extracted from suspended material.

238. RICE, R.J.

1979: The Hydraulic Geometry of the Lower Portion of the Sunwapta River Valley Train, Jasper National Park, Alberta; Unpublished M.Sc. Thesis, Department of Geology, University of Alberta, Edmonton, 160 p.

ABSTRACT:

Morphologic and hydraulic data were gathered from 60 gravel channels (20/reach) on the Beauty Creek Flats section of the proglacial Sunwapta River during August 4-15, 1977. Four power functions (log-linear; width, average depth, average surface velocity and water surface slope) are determined for each reach and for Beauty Creek Flats as a whole with discharge as the independent parameter in all cases. A downstream hydraulic geometry interpretation indicates that the downstream reduction in the median grain size, D_{50}, is mainly responsible for the variation in channel behaviour. In all three reaches of Beauty Creek Flats the primary adjustment of the channels to an increased discharge is an increase in the width of the flow.

It appears that the width exponent (b) may be used as an index of braiding intensity.

The b-f-m diagram of Rhodes (1977) is used to determine the at-a-station variation in channel behaviour downstream.

The hydraulic geometry relations determined for Beauty Creek Flats as a whole are compared to corresponding relations from other gravelly, glaciofluvial environments (Fahnestock (1963), Church (1972) and Arnborn (1955)). The best comparison is between the Sunwapta River equations and those of Fahnestock determined for the White River. A difference in channel behaviour between the Sunwapta River and the White River as a group and the Baffin Island sandar (Church) and the Hoffellssandur (Arnborg) as another group is suggested to be caused by greater bank stability in the Arctic studies.

It is suggested that there is a similarity in channel response among areas of braided gravel outwash provided associated climatic conditions are similar.

The width and velocity relations of Church and the depth relation of this study (eq. 4.14) are suggested for estimating channel response on braided gravel outwash in the Arctic environment. The width and velocity relation of Fahnestock and the depth relation of this study are suggested for similar usage in the non-Arctic environment.

239. RICE, R.J.
1982: The Hydraulic Geometry of the Lower Portion of the Sunwapta River Valley Train, Jasper National Park, Alberta; In: Research in Glacial, Glacio-fluvial and Glacio-lacustrine Systems; Proceedings of the 6th Guelph Symposium on Geomorphology 9-10 May, 1980, Editors R. Davidson-Arnott, W. Nickling and B.D. Fahey, Geographical Publication No. 6, Department of Geography, University of Guelph, Geo Books Norwich, Geo Abstracts, Norwich, p. 151-173.

ABSTRACT:

Morphologic and hydraulic data were gathered from 60 gravel channels (20/reach) on the Beauty Creek Flats section of the proglacial Sunwapta River during August 4-15, 1977. Four power functions (log-linear: width, average depth, average surface velocity and water surface slope) are determined for each reach and for Beauty Creek Flats as a whole with discharge as the independent parameter in all cases. A downstream hydraulic geometry interpretation indicates that the downstream reduction in the median grain size is mainly responsible for the variation in channel behaviour. In all three reaches of Beauty Creek Flats the primary adjustment of the channels to an increased discharge is an increase in the width of the flow.

It appears that the width exponent (b) may be used as an index of braiding intensity.

On Beauty Creek Flats slope is an independent parameter and is not a significant influence in the nature of the anabranch adjustment.

The hydraulic geometry relations determined for Beauty Creek Flats as a whole are compared to corresponding relations from other gravelly, glaciofluvial environments (Fahnestock, 1963; Church, 1972; and Arnborg, 1955). The comparison suggests that Arctic and non-Arctic outwash may be distinguished by the magnitude of the width and velocity exponents. The former is lower in an Arctic environment while the latter is higher. This suggests that there may be a similarity in channel response among areas of braided gravel outwash provided associated climatic conditions are similar. If additional data on channel adjustment on areas of gravelly outwash supports a similarity there may be potential for the development of a set of hydraulic geometry equations for each environment which could be used as predictors of channel behaviour.

240. RIDGWAY, T.P. and McLEAN, D.G.
1980: Data Report - Channel Characteristics of Red Deer River Prior to Construction of Dickson Dam; Transportation and Surface Water Engineering Department, Alberta Research Council, Report SWE 80-1, 122 p.

ABSTRACT:

Channel cross section, bed and bank material samples and some miscellaneous suspended sediment samples are presented to document the channel characteristics of the Red Deer River prior to construction of Dickson Dam. The scope of the field investigation extended from the mouth of the Raven River to the town of Red Deer. The permanent bench marks established at each cross section location will allow surveys to be made after the dam's construction to measure the impact of the dam on the river's regime.

241. RIESEN, H.G. and FORSYTH, G.T.
1960: Edwards-Jackfish Creeks Floodway. Lake Dauphin Silting Problem; Internal Report, Department of Agriculture, Prairie Farm Rehabilitation Administration, Engineering Branch, Winnipeg, 13 p.

ABSTRACT:

This report provides a comparison of two possible solutions to the Lake Dauphin silting problem caused by the Edwards-Jackfish Creeks Floodway. The report gives a detailed analysis of the work, costs and probable results and drawbacks involved in either installing additional drop structures within the floodway or developing a new silting basin which would involve a minor diversion.

242. ROGERS, J.S., HUANG, P.M. and LIAW, W.K.
1980: Chemical Dynamics of Mercury Sorption and Desorption of Freshwater Sediments; International Association of Theoretical and Applied Limnology, Proceedings, Vol. 20, No. 1, p. 174-180.

ABSTRACT:

This study reports the rates of sorption and desorption of mercury as influenced by temperature and the binding capacity for mercury of selected lake, river and creek sediments in the Canadian Prairies. Results indicate that the sorption and desorption of mercury by sediments obey multiple first order kinetics. The initial fast sorption process is exothermic. The rate constants of the slow sorption process exhibit little trend to temperature changes while the rate constants of the fast sorption range from 14 x 0.01 to 95 x 0.01 per hr and are 2-100 times higher than those of the slow sorption. The rate of the initial fast desorption process increases with increasing temperature, while the rate constants of the slow desorption decrease with increasing temperature. The capacity of the sediments to bind mercury varies from 17-14 mg mercury per g of sediment. The high sorption capacity of the sediments for mercury and the slow desorption process relative to the sorption process show that the bulk of mercury in aquatic environments is sorbed onto the sediments and may continue to be available from the sediments over some time.

243. ROSENBERG, D.M. and Snow, N.B.
1975: Ecological Studies of Aquatic Organisms in the Mackenzie and Porcupine River Drainages in Relation to Sedimentation; Fisheries and Marine Services, Environment Canada, Technical Report No. 547, 86 p.

ABSTRACT:

A review of recent literature on the effects of increased sedimentation on aquatic biota is presented. Timber harvesting, forest fires, road construction and operation, and channelization of rivers and streams were identified as the major possible sources of unnatural increases in suspended and settled sediments in northern watersheds. Detrimental effects of increased suspended and settled sediments can result, singly or in combination, from a reduction in light penetration, mechanical abrasion, toxicants adsorbed to sediment particles, and changes in substrate. Specific detrimental effects, due to a variety of watershed disturbances, on flora and fauna are discussed. Recovery rates of flowing waters from increased sedimentation vary from a few days to not at all and depend, basically, on characteristics of the river or stream, the severity of sediment addition, and availability of undamaged areas as sources of recolonization. It would appear from the literature that unnatural increases in suspended sediment concentrations of most flowing waters should not result in a concentration greater than 80 mg per liter to ensure protection of aquatic life. A flowing-water habitat should always be able to carry away an increased sediment load to prevent permanent sedimentation of the substrate. Future research needs on the effects of unnatural increases of sediment on aquatic biota include a standardization of measurements and methods used, quantitation of terms such as "adverse", "detrimental", "deleterious|, and "damage", and laboratory experimentation complementary to descriptive and experimental field data.

244. ROSENBERG, D.M. and SNOW, N.B.
1977: A Design for Environmental Impact Studies with Special Reference to Sedimentation in Aquatic Systems of the Mackenzie and Porcupine River Drainages; Proceedings of the Circumpolar Conference on Northern Ecology, September 15-18, 1975, National Research Council, Ottawa, p. III-65-III-78.

ABSTRACT:

The first major environmental impact study to be done in Canada's north was carried out under the auspices of the Environmental-Social Committee, Task Force on Northern Oil Development. Our involvement in this study led to the development of what we consider to be a suitable approach to future environmental impact studies. This approach consists of eight steps which we have illustrated with data from our physical and biological studies on sedimentation in the Mackenzie and Porcupine River drainages. We suggest that the most important function of an environmental impact study is prediction of the effects of an impact before it occurs and recommendation of mitigation procedures.

Likely, settled moreso than suspended sediment is critical to zoobenthos communities. The amount of sediment that settles depends on the carrying capacity of the river for sediment and/or the amount of sediment added. The magnitude of the effect will depend on the amount of sediment that settles. The duration of the effect will depend on whether the annual maximum discharge period is capable of removing the added sediment from the substrates and, if it is capable, the length of time until the removal occurs. Therefore, verification that a river is technological disturbance should be sought. Failing the river's capability to do that, sediment addition should be reduced as much as possible and verification sought that the annual maximum discharge can remove the added sediment from the river substrate. Addition of sediment to rivers in which annual maximum discharge cannot remove the added sediment should be avoided or long-term changes in the biota will result.

Attempts to set a priori tolerance levels for controlling the amount of sediment unnaturally added to systems with natural sediment transport rates as diverse as those in the Mackenzie and Porcupine drainages are unsuitable.

245. ROSENBERG, D.M. and WIENS, A.P.
1975: Experimental Sediment Addition Studies on the Harris River, N.W.T., Canada: The Effect on Macroinvertebrate Drift; International Association of Theoretical and Applied Limnology, Proceedings, Vol. 19, p. 1568-1574.

ABSTRACT:

Experimental approaches are necessary to study the mode of action of suspended and settled sediments and the responses of freshwater fauna to known concentrations of suspended and settled sediments. The only recent experimental study involving freshwater zoobenthos was done on a river in Indiana (Gammon 1970).

The first of a series of studies on the effects of artificially increased suspended sediment concentrations on various aspects of benthic macroinvertebrate life in northern Canadian rivers were carried out by us in the summer of 1973. This study dealt with the response of benthic macroinvertebrates, as measured by numbers of animals in the drift, to additions of predetermined amounts of river bank sediment.

246. ROTHWELL, R.L.
1977: Suspended Sediment and Soil Disturbance in a Small Mountain Watershed After Road Construction and Logging. Proceedings of the Alberta Watershed Research Program Symposium, R.H. Swanson and P.A. Logan, Compilers, August 31-September 2, Edmonton, Alberta, p. 285-300.

ABSTRACT:

The effects of road construction and logging on water quality in Marmot Creek Experimental Watershed were studied in terms of suspended sediment and soil disturbance. The objective of the study was to demonstrate that water quality deterioration associated with forest harvesting can be prevented by careful planning of road construction and logging. Roads were constructed in Cabin sub-basin 2 years before logging. Logging was done by clear-cut blocks, with logs skidded by rubber-tired skidders and crawler tractors. Suspended sediment record was obtained on a daily basis during the summer flow season, 4 years before roads and logging and 3 years afterwards. Soil disturbance and erosion caused by roads and logging were evaluated by mapping and reconnaissance of disturbed areas.

Soil exposure from roads and logging affected 25% of the total area of Cabin sub-basin. Soil exposure on cut blocks averaged 32%, with most of it caused by skidroads. Mapping and reconnaissances of disturbed areas showed very little erosion and no sediment transport towards streams. Analysis of sediment data showed no increases in sediment concentrations or discharges that could be associated with roads or logging.

247. ROTHWELL, R.L.
1983: Erosion and Sediment Control at Road-stream Crossings; The Forestry Chronicle, Vol. 59, No. 2, p. 62-66.

ABSTRACT:

The effectiveness of a "brush mulch" to control erosion and sediment at road-stream crossings was evaluated by measurement and comparison of upstream and downstream suspended sediment. The brush mulch consisted of logging debris, such as branches, tree tops and logs 2-15 cm in diameter, laid on the ground to intercept and to slow overland flow and to trap sediment. Two treatments were defined and tested. Treatment No. 1 was a brush mulch and grass-fertilizer mixture applied by hydroseeding to three bare soil road-stream crossings. Treatment No. 2 was a grass-fertilizer mixture applied by hydroseeding to another three road-stream crossings.

Total seasonal and storm sediment production for mulched and unmulched crossings averaged 31 and 37, and 566 and 2297 kg/day/ha, respectively. Tests showed significant differences between treatments for both seasonal and storm sediment production. The levels of significance were low because of high variability in sediment production among treatments and road crossings. Frequent onsite inspections during storm and nonstorm conditions, however, identified sources of variability and supported a final conclusion that the brush mulch was effective for erosion and sediment control at road-stream crossings.

248. SAMIDE, E.W.
1971: Sediment Transport Measurements; Unpublished M.Sc. Thesis, Department of Civil Engineering, University of Alberta, 55 p.

ABSTRACT:

Sediment transport measurements were taken on the Elbow River at Bragg Creek, the North Saskatchewan River at Nordegg and the North Saskatchewan River at Wilson's Bridge. The Elbow River site was studied previously by A.B. Hollingshead in 1967 and 1978.

Bed-load discharge was measured with three different portable bed-load samplers at Nordegg and Bragg Creek. These samples were the 1/4 inch mesh basket, the 1/2 inch mesh basket and the V.U.V. samplers. Bed-load discharge was also determined by direct measurements on the refilling rate of a large pit excavated in the Elbow River bed. Suspended sediment measurements were carried out at all thres sites using depth-integrating samplers. The velocity distribution was measured for several different stages of flow. A hydrophone was used to determine the start and width of bed-load movement.

The efficiency of the 1/4 inch mesh basket was determined for certain low flows on the Elbow River. Relative sampling efficiencies between the bed-load samplers were determined with the most efficient sampler being the 1/2 inch mesh basket. The bed-load discharge obtained from bed-load sampling was related to fluid discharge. Bed material discharge was determined using graphs which were developed by Cooper and Peterson (1968). The calculated bed material discharge was then compared with measured bed-load discharge. The bed-load material was analyzed for size-distribution and compared to the size-distribution obtained from bed-load samples.

The relationship between suspended sediment discharge and bed-load discharge was calculated for Bragg Creek and for Nordegg. The total sediment yield at all three sites was determined.

A statistical study on bed-load movement is recommended for Bragg Creek. An efficient method of measuring the refilling rates of a large volumetric pit would enable the exact determination of bed-load sampler efficiencies.

249. SAMOILOFF, M.R., ARNOTT, E., WEBSTER, G.R.B., BELL, J. and BIRKHOLZ, D.A.
1983: Evaluation of Levels and Kinds of Toxic Effects Associated with Chemical Fractions of Sediment from Tobin Lake, Saskatchewan; Proceedings of the 9th Annual Aquatic Toxicity Workshop, 1-5 Nov., 1982, Edmonton, Alberta, Canadian Technical Report, Fisheries and Aquatic Sciences, No. 1163, p. 154-164.

ABSTRACT:

Two short-term biological tests, the Salmonella typhimurium (Ames) test for mutagenesis and the Panagrelius redivivus (nematode) developmental assay were used on chemical extracts of Tobin Lake,

Saskatchewan, sediment samples. Two types of biological effect could be detected with S. typhimurium; growth, and (2) mutagenesis. The Panagrellus redivivus developmental assay detects 4 types of effect (in decreasing order of priorized risk); (1) lethality, (2) sublethality, (3) inhibition, (4) mutagenesis. The chemical extraction protocol involves both differential solubility and elutability from florasil. Sites near the point where the Saskatchewan River enters the lake show maximal toxic effects in a neutral fraction eluting from florasil with 1:1 hexane-dichloromethane.

Sites further downstream show toxicity associated with more polar fractions. Fifty-four potentially toxic compounds were identified in the toxic neutral fraction from the upstream sites although only 5 compounds were found in the toxix fraction from both upstream sites. These compounds are 2-nonenal, hexyl-e methyl cyclopentane, 1,9-nonanediol, tetradecanol and benzaldehyde.

250. SCHINDLER, D.W., WAGEMANN, R. and HESSLEIN, R.H.
1979: Interim Report on the Acidication of Lake 223, Experimental Lakes Area; Background Data, the First Year of Acidification; Report to the Alberta Oil Sands Environmental Research Program, Edmonton, 90 p.

ABSTRACT:

Data on the chemistry and biology of Lake 223 are presented for two background years, 1974 and 1975, and for 1976, when sulphuric acid was added to the lake. Four additional years of acidification are planned, eventually reaching a pH of about 5. Background data are given for morphometry, substrate type, pH, sulphate, dissolved inorganic carbon, bicarbonate, dissolved organic carbon, suspended phosphorus; silica, calcium, magnesium, sodium, potassium, iron, manganese, zinc, copper, cobalt, lead, cadmium, suspended carbon, total dissolved nitrogen, suspended nitrogen, nitrate, ammonium, total dissolved phosphorus, chromium, aluminum, chlorophyll, phytoplankton, primary production, respiration, light, temperature, benthic emergence, crayfish, and fish populations. The only observable chemical effect in 1976, the first year of acidification, was a halving of the dissolved inorganic arbon concentration. Short-term effects on the biota were not observable; acidification continues. Mass-balance calculations allowed identification of two possible mechanisms in addition to dissolved bicarbonate which might buffer the lake system: lake sediments and dissolved colloids (humic substances). Pilot experiments were done in 10 m diameter tubes at pH 5 and 6, in order to anticipate changes which might take place in the lake as pH is lowered in future years. These experiments concentrated largely on chemistry, particularly trace metals. As pH dropped to 6 and below, aluminum, iron, manganese, zinc, thorium, and possibly cadmium were mobilized from sediments.

251. SCHWEYEN, T. and LAST, W.
1983: Sedimentology and Paleohydrology of Waldsea Lake, Saskatchewan; Proceedings of the 3rd Biennial Plains Aquatic Research Conference, 24-25 August, Montana State University, Bozeman, p. 45-59.

ABSTRACT:

Waldsea Lake is a small meromictic saline lake in central Saskatchewan. The chemocline was first measured at 4 m depth in 1971, and has since dropped to 9 m. Despite its change in elevation, it is still capable of supporting a bacterial plate composed primarily of *Chlorobium* spp. Major ion chemistry shows that the lake is of the Mg-Na,SO_4-Cl type. The lake irregularly allows massive precipitation of carbonates in the form of aragonite and also occasionally gypsum. These events are rather shortlived, and are represented in the sediment as laminations of nearly pure represented in the sediment as laminations of nearly pure aragonite of gypsum. Because the lake occupies a closed basin the lacustrine fill provides a detailed record of the late Holocene history of the lake. Sediment cores of the upper 4 m show a complex history of clastic, chemical, and organic sediment input. Superposed on this is an intricate assemblage of early diagenetic effects. The allogenic component consists of fine-grained quartz, dolomite, calcite, deldspars, and clays. Endogenic components include aragonite and gypsum. Early diagenetic dolomite, gypdum, and pyrite are also present. Organic content varies significantly but irregularly throughout the cores. Radiocarbon dating suggests that the upper 4 meters of sediment were deposited during the last 4000 years, and that sedimentation rates have varied significantly. Stratigraphically, these sediments indicate a small shallow, hypersaline lake with extensive mudflats existed in the basin about 4000 years B.P. With the exception of several small reversals, the lake has been continually deepening and becoming less saline throughout its history, likely due to the effects of a moderating climate.

252. SEAGEL, G.C.
1971: The Morphological and Sediment Characteristics of the Elbow River Basin; Unpublished M.Sc. Thesis, Department of Geography, University of Alberta, Edmonton, 182 p.

ABSTRACT:

This study provides information on the distribution of surficial sediments, and morphological characteristics of the Elbow River basin, in order to facilitate future research in this area. Discussion of the evolution and present behaviour of the Elbow River, and notable events concerning the development of the landscape is included.

Sediment samples and morphological information were collected in the field. The results of the laboratory analysis of grain size were analysed statistically using principal component analysis.

The morphological information was supplemented by mapping from aerial photographs. Results included a morphological map and a map of the surficial geology.

The conclusions of this study are:

1. Principal component analysis can be used to discriminate between sediment types.
2. Neither antecedence nor superimpositions are conclusively proven to be responsible for discordance between the Elbow River and geological structure in the foothills region of the study area.
3. The distribution of the surficial material is closely related to limits of advance of Cordilleran and Laurentide ice masses.
4. The present Elbow River is in a state of quasi-equilibrium, due to a decrease in mean annual flow since neo-glacial times which has resulted in a change in the sediment transport characteristics. The result is adjustment of slope in the longitudinal profile to: (a) changes in the amount and size of sediment transported; and (b) the lowering and/or removal of the influence of 'knickpunte'.

253. SHAW, J. and KELLERHALS, R.
1977: Paleohydraulic Interpretation of Antidune Bedforms with Applications to Antidunes in Gravel; Journal of Sedimentary Petrology, Vol. 47, No. 1, p. 257-266.

ABSTRACT:

Antidune-like bedforms in the alluvium of the gravel-bedded North Saskatchewan River, Alberta, form regular trains of gravel mounds. Crest lengths, transverse to the flow, are about 2 meters, and crest spacing, along the flow, is between 2 and 3 meters. Flume experiments with gravel beds show that published equations describing flow conditions for the formation of antidunes on sand beds are applicable to antidune formation on gravel beds. Paleohydraulic reconstructions based on antidunes give rough estimates for depth and velocity, but cannot be used to estimate bedslope. Comparison of slope estimates based on antidune dimensions and observed bedslopes show the inadequacies of such estimates.

254. SHAW, J. and KELLERHALS, R.
1982: The Composition of Recent Alluvial Gravels in Alberta Riverbeds; Alberta Research Council, Bulletin No. 41, 151 p.

ABSTRACT:

A large data set of grain-size distributions and lithologic composition is presented for bed material in 12 Albertan rivers over a total sampled length of 7 500 km. The hydraulic, hydrologic, and geomorphic characreristics of the rivers are described briefly. Details of sample collection including geographic location and site descriptions are given. The data are presented in tables of grain-size distributions and percentage contributions of lithologic types to grain-size classes coarser than 2 mm. An estimate of significance of the constituent grain-size distributions is given. Eight grain-size parameters are estimated from the sample distributions: geometric means (DG) for the granite, limestone, quartzite, and total gravel fractions; and D sub 50 and D sub 90 for the total samples and the gravel fractions. Plots are given for downstream changes in lithological composition and grain-size parameters. The downstream change in lithological composition reflects the relative resistance of quartzite and limestone in upstream reaches, and also illustrates the increasing importance of erratic, granitic Shield lithologies which have been introduced to downstream reaches by continental glaciation. The westward limit of Shield erratics in stream bed materials is used to estimate the maximum limit of Laurentide glaciers. These estimates are shown to correspond closely with mapped limits, with the exception of the Athabasca and McLeod estimates which lie much further east than the mapped limits. The variability of grain size in large gravel-bedded streams is treated by analysis of variance. Variance between samples (at a site) is highly significant, while downstream variance is even more significant. Downstream changes in grain size are considered in the course of this study in relation to the region's geomorphic history and the processes of differential fluvial transport and abrasion. Three distinctive reaches are noted in the large, well-sampled rivers. The first, the moutain reach, in which aggradation in lakes and behind alluvial fans takes place, shows an increase in grain size as one moves downstream. Then, there is the central gravel reach which shows an exponential decrease in grain size with distance, corresponding to Sternberg's relationship. This central reach terminates abruptly, however, with a change from a gravel to a sand bed, which constitutes the third type of reach observed. The sand shows little change in size regardless of downstream location. Diminution coefficients for rivers and alluvial fans are presented to show the dominant influence of differential transport in the aggrading fan environment. Comparison of diminution coefficients for various river gravels with abrasion coefficients established in controlled experiments, reveals that abrasion coefficients consistently underestimate diminutuon coefficients. Analysis, which uses diminution and abrasion coefficients for different lithologies, reveals that the abrasion coefficient for rivers can be subdivided into two components - "abrasion during transport" and "abrasion at rest." The analysis indicates that the condition of "abrasion at rest" is dominant in Albertan rivers. Grain-size distributions for alluvial gravels are commonly bimodal. The gravels of this study show a deficiency in the range from coarse sand to granules. This deficiency relates to the style of sediment transport, whether suspended or bedload.

255. SINGHROY, V.H.
1977: Sedimentation and Erosion Studies in Wilson Creek Watershed, Manitoba, With Particular Reference to Shale Bank Retreat; Unpublished M.A. Thesis, University of Manitoba, Winnipeg, Manitoba, 249 p.

ABSTRACT:

Wilson Creek Watershed is located on the eastern slopes of Riding Mountain National Park in Manitoba and covers an area of 8.18 square miles. It contains two main streams--Packhorse and Baldhill--which joint to form Wilson Creek at the foot of the Manitoba Escarpment.

Field data collected from 1964 to 1974 show that the 47 shale banks are the main source of sediment. The shale banks are eroded in horizontally bedded calcareous shale that weathers to produce screes at their bases. Mean slope angles of 35 ancres slopes, measured over a ten-year period, range between 32.55 and 29.97 degrees. Moreover, it has been shown statistically that the instability of shale screes is a function of their location 'at' or 'away' from the creek. The annual rate of retreat of the shale banks is 0.5 feet for Packhorse and 0.2 feet for Baldhill. Over the period 1964-1972, there was a substantial net loss of debris on Packhorse Creek. The cumulative size of screes along Packhorse Creek has, therefore, markedly diminished, whereas there has been an overall growth of screes on Baldhill Creek.

Longitudinal profile determinations revealed a general rise in stream bed. Degradation and aggradation studies show that lateral erosion was more extensive than vertical erosion and aggregate deposition was three times greater than aggregate erosion.

Weathering is the most extensive process producing shale plates which are subsequently removed by mass wasting, wind transportation and surface water erosion. Soil creep, slumping and gullying are confined to till slopes in the upper reaches of the Watershed; talus shift, wind erosion, debris fall and basal undercutting predominate on the shale screes and free face banks.

Within the Watershed, log cribs and rip raps are the most effective bank protection methods. Revegetation by willows in valuable in promoting shale stabilization. The sediment trap at the foot of the escarpment is not only a flood control device, but an efficient system for monitoring bedload.

256. SLAYMAKER, O.
1972: Sediment Yield and Sediment Control in the Canadian Cordillera; In: Mountain Geomorphology, O. Slaymaker and H.J. McPherson, Editors, Tantalus Press, Vancouver, p. 235-245.

ABSTRACT:

This paper examines sediment dynamics (sediment distribution, sediment yield and sediment control measures) in numerous rivers in

Alberta and British Columbia. These rivers have been arbitrarily divided into three spatial scales: 1) larger than 25,000 km^2, 2) 250-25,000 km^2 and 3) smaller than 250 km^2.

257. SMITH, D.G.
1972: Aggradation and Channel Patterns of the Alexandra-North Saskatchewan River, Banff National Park, Alberta; In: Mountain Geomorphology, O. Slaymaker and H.J. McPherson, Editors, Tantalus Press, Vancouver, p. 177-185.

ABSTRACT:

This paper examines an aggrading river and determines it's processes, the rates of deposition and the causes of variation in channel pattern.

258. SMITH, D.G.
1973: Aggradation of the Alexandra-North Saskatchewan River, Banff Park, Alberta; In: Fluvial Geomorphology, M. Morisawa, Editor, Proceedings of the 4th Annual Geomorphology Symposium, Binghamton, New York, September 27-28, 1973, p. 201-219.

ABSTRACT:

Aggradation has been the dominant fluvial condition for the past 2450 years in the two meltwater rivers fed by the Columbia Icefield in Banff National Park. Evidence of past valley filling consists of buried volcanic ash, peat, wood and fluvial sediment found in drill holes. Present aggradation is demonstrated by the presence of buried lower tree trunks and direct measurement of sedimentation with stakes.

The most convincing evidence which supports the existence of aggradation was the buried layer of volcanic ash, which has been dated at 2450 years B.P. Used as a stratigraphic time marker, the profile of ash depth was plotted below the long profile of the present river surface. The difference between the two profiles represents the thickness of alluvium which has been depositing over the past 2450 years. The maximum depth to the ash layer was 25.5 feet.

Aggradation is directly related to one of two types of controls. Upstream control occurs where excessively high sediment loads deposit and form a wedge of sediment over time, thickest near the source and thinning downriver. With upstream control, the dominant sediment is coarse outwash deposited as gravel bars in shifting braided channels. Braids in outwash are typically steep, shallow and, in particular, unstable over time.

In contrast, downstream control, synonymous with base level control, causes a backwater reach, forming a wedge of sediment which thins in the upstream direction from the control point. Aggradation processes caused by downstream control consists of overbank flooding and deposition of fines onto levees, backswamps and floodplain-like surfaces. Distinct from braids in outwash, anastomosed channels which form in backwater reaches are deep, gently slopes channels and shift laterally at very slow rates. Stability of anastomosed channels is attributed to roots of grass and shrub vegetation, which provide a riprap-like protection to silt banks from fluvial erosion. While braided and anastomosed channels have similar patterns, they differ in process.

259. SMITH, D.G.
1979: Effects of Channel Enlargement by River Ice Processes on Bankfull Discharge in Alberta, Canada; Water Resources Research, Vol. 15, No. 2, p. 469-475.

ABSTRACT:

Results from 24 rivers studied in Alberta show that bankfull recurrence intervals average 16.7 yr, ranging between 2.4 and 45 yr. These results differ sharply from the average of 1.6 yr for rivers in the warmer countries such as Great Britain, Australia, and the United States. The difference in frequency of return period for Alberta rivers may be attributed to channel enlargement caused by the occurrences of scour from ice breakup, drives, and jams of unknown frequencies. The enlarged channel areas (cross sections) bankfull average 2.6 times larger, but due to comparison adjustments, may be 3 times larger than comparable rivers at bankfull in the United States, and are thus able to carry an average of 4.7 times more discharge, taking into account the increase in velocity.

260. SMITH, D.G.
1983: Anatomosed Fluvial Deposits: Modern Examples from Western Canada; In: Modern and Ancient Fluvial Systems; J.D. Collinson and J. Lewin, Editors, Special Publications Number 6 of the International Association of Sedimentologists, Blackwell Scientific Publications, Oxford, Great Britain, p. 155-168.

ABSTRACT:

Facies of two Canadian modern anastomosing river systems are discussed, the upper Columbia and lower Saskatchewan Rivers, which occur in intermontane and plains settings respectively. Both systems contain aggrading, multiple, low gradient, sand bed channels with adjacent splay, levée, and shallow wetland environments, all aggrading in accordance with channel sedimentation. While aggrading cross-valley alluvial fans or subsidence tend to control sedimentation rates in intermontane valleys, basin subsidence and/or regional tilting controls deposition rates in plains settings.

Sedimentation style in the upper Columbia River valley (120 x 1.5 km) consists of low-sinuosity, stable channels, depositing multi-storied channel sands and numerous sandy crevasse splay deposits. Channel deposits form as sand stringers laterally contained by deposits of levée silt and lacustrine mud. Aggrading at an average rate of 60 cm per 100 years over the past 2500 years, the anastomosing system is very dynamic, exhibiting avulsions and channel fills.

Deposition in the lower Saskatchewan River valley (120 x 80 km) a much wider basin with slower aggradation rates (29 cm 100 yr^{-1}, C-14 date on peat buried beneath a levée) results in laterally extensive sheets of overbank levée deposits of fine sand which grade into even more laterally extensive thick deposits of peat. With time, some dominant channels become highly sinuous, thus causing increased flow resistance, major avulsions upriver and eventual channel filling and abandonment. Facies differences of the two anastomosed river systems are believed to be caused by both the rate of sedimentation and width of the sedimentary basin.

261. SMITH, D.G. and PUTNAM, P.E.
1980: Anastomosed River Deposits: Modern and Ancient Examples in Alberta, Canada; Canadian Journal of Earth Sciences, Vol. 17, No. 10, p. 1396-1406.

ABSTRACT:

The anastomosed fluvial system is proposed as an environment of deposition for some overbank deposits, coal, and coarse channel sediments (sandstone and conglomerate) in the Rocky Mountain molasse (Mesozoic-Tertiary) of Alberta and British Columbia. The system consists of rapidly aggrading channels and adjacent wetlands, caused by a rising local base level downriver (i.e., alluvial fans) or basin subsidence. Multiple, multi-storied anastomosed channel deposits generally have low gradients, variable sinuosities, and low width/depth ratios. Anastomosed fluvial facies are similar to some river-dominated low energy deltaix facies; therefore, many of the deposits and facies geometries are similar. Similarity occurs because the fluvial processes and morphologies are similar. For example, as with lower deltaic plains, stable anastomosed channels are related to gently gradients and high amounts of silt, clay, and vegetation in the banks. Channel stability subsequently accounts for a stable deposition environment favourable for the accumulation of organic material. Wetland environments cover the largest area (estimated 60-90%) of anastomosed systems, while channels, levees, and crevasse splays are minor in extent. Modern and ancient examples of anastomosis are described to provide a basic depositional framework. The lower reach (valley fill) of the modern Alexandra River in Banff Park is the modern example described. In east-central Alberta and southwest Saskatchewan, the hydrocarbon-bearing channel sandstones of the upper Mannville subgroup (Vigrass) are interpreted as an ancient (Lower Cretaceous) anastomosed system of very large scale (80 km x 300 km). We believe that the interpretation of environments of deposition in some ancient fluvial sequences of molasse deposits has been limited. This is due to the fact that anastomosed systems have only recently been understood as a unique fluvial style related to specific causal conditions. We suggest that the rapid subsidence along the western margin of the molasse foreland, coupled with high sediment loads from nearby mountain building (i.e., Rocky Mountain), would represent suitable conditions for anastomosis as well as graded meandering or aggrading braided fluvial styles. These same conditions would also apply to molasse deposition in intermontane basins.

262. SMITH, D.G. and SMITH, N.D.
1980: Sedimentation in Anastomosed River Systems: Examples from Alluvial Valleys near Banff, Alberta; Journal of Sedimentary Petrology, Vol. 50, No. 1, p. 157-164.

ABSTRACT:

Three anastomosed river systems are described. Each reach consists of an interconnected network of low-slope, narrow and deep, straight to sinuous, stable channels that transport coarse sand and gravel. Channels are separated by levees and wetlands composed of silt/mud and vegetation, gravel-bed braided channels occur upstream from each anastomosed system, joined by a transitional reach comprising stable, elongate, silt islands within braided channels. The three anastomosed reaches have formed upstream from elevating base levels caused by deposition of alluvial fans across trunk valleys. Rapid aggradation of floodplain alluvium is confirmed by buried volcanic ash layers. Channel migration is inhibited by root-stabilized banks which, combined with rapid vertical aggradation, results in production of stronger-like, coarse-grained channel deposits surrounded by overbank fines in stratigraphic cross sections. Although it is unlikely that such small base-level controls (alluvial fans) could produce extensive anastomosed deposits, other mechanisms such as glacial moraines, isostatic rebound, or marine transgressions could provide plausible controls for yielding important contributions to the stratigraphic record.

263. SMITH, N.D.
1975: Sedimentary Environments and Late Quaternary History of a "Low-Energy" Mountain Delta; Canadian Journal of Earth Sciences, Vol. 12, No. 12, p. 2004-2013.

ABSTRACT:

Due to its low input of coarse sediment, Upper Waterfowl Lake, in Banff Park, Alberta, has developed a delta atypical of lacustrine deltas in this high mountain region: lack of foresets, vertically aggrading stable distributary channels, and a surface composed of mostly fine-grained floodplain materials. Deltaic progradation has outrun the supply of coarse sediment, resulting in entrapment of all gravel and coarse sand in proximal channels.

Data provided by auger samples, including stratigraphic positions of Mazama and Bridge River volcanic ashes, suggest the lake was formed about 8800 years ago when deposition of a large alluvial fan blocked the Mistaya River at the upper end of Lower Waterfowl Lake. The delta has undergone two progradations, one beginning at the lake's time of origin, the other following a renewed lake level rise some 2300 years ago. Mean aggradation rates since Mazama time (6600 y BP) have been approximately steady at about .05 cm/y. Pre-Mazama lake sediments, however, were deposited more than twice as fast as a result of accelerated sedimentation rates that accompanied deglaciation.

264. SMITH, N.D.
1978: Sedimentation Processes and Patterns in a Glacier-fed Lake with Low Sediment Input; Canadian Journal of Earth Sciences, Vol. 15, p. 741-756.

ABSTRACT:

Hector Lake, situated in the eastern Rocky Mountains of western Alberta, is fed primarily by nival and glacial meltwater. During summer when the lake is thermally stratified, inflowing water and fine sediment enter the lake as overflows and shallow interflows that are transformed into complex, but mostly downlake, epilimnial currents generated by downlake katabatic winds. Coriolis deflections produce a strong right-hand tendency in sedimentation patterns, with resulting crosslake (south-to-north) as well as downlake (west-to-east) proximal-distal trends: reduction in grain size, sedimentation rates, total carbonate, dolomite/(dolomite + calcite) and varve thickness.

Laminae in bottom sediments are produced by inflow variations that are largely dependent upon air temperature. Five orders of inflow, and thus sediment input, variation capable of producting laminae are recognized; diurnal, subseasonal (short-term weather changes), seasonal (nival melt vs. glacial melt), annual and exceptional inflow events. Based upon laminae character, four facies of glacier-derived and one of non-glacier-derived bottom sediments are recognized in Hector Lake.

265. SMITH, N.D.
1981: The Effect of Changing Sediment Supply on Sedimentation in a Glacier-fed Lake; Arctic and Alpine Research, Vol. 13, No. 1, p. 75-82.

ABSTRACT:

Bow Lake, Alberta, Canada, is a deep, thermally stratified alpine lake fed by an overland meltwater stream from Bow Glacier. The glacier has been generally receding from its Neoglacial maximum, and around 1955 a pond began to form at the terminus. Prior to pond development, sedimentation in Bow Lake was dominated by underflows which formed thick varves in the lower areas of the lake floor. Since 1955, however, the pond has deprived the stream of much of its sediment load, and inflows are now dispersed through the lake mainly as rightward-deflected interflows moving above the hypolimnion. The effect of the pond, therefore, has been to alter the pattern of sedimentation in the lake as well as to reduce its overall rate of deposition.

266. SMITH, N.D. and SMITH, D.G.
1984: William River: An Outstanding Example of Channel Widening and Braiding Caused by Bedload Addition; Geology, Vol. 12, p. 78-82.

ABSTRACT:

The lower William River in northwestern Saskatchewan, Canada, presents an excellent and unambiguous example of rapid channel adjustment to abrupt additions of sandy bedload. A relatively narrow and deep single-channel stream as it flows northward to Lake Athabasca, the river picks up a 40-fold increase of bedload over a 27-km reach as it encounters a large dune field just south of the lake. As a result of the large infusion of eolian sand, the channel develops a thoroughly braided pattern while undergoing a 5-fold increase in width and a 10-fold increase in width/depth ratio.

267. SMITH, N.D. and SYVITSKI, J.P.M.
1982: Sedimentation in a Glacier-fed Lake: The Role of Pelletization on Deposition of Fine-grained Suspensates; Journal of Sedimentary Petrology, Vol. 52, No. 2, p. 503-513.

ABSTRACT:

Bow Lake is a small alpine lake in western Alberta, Canada, mainly fed by glacial meltwater. Suspended sediment loads, high only during summer months, are transported through the lake dominantly by interflows within the epilimnion. Consideration of interflow velocities and particle settling rates suggests that most clay supplied by stream inflow should be transported out of the lake during summer when thermal stratification is best developed. Field observations, however, show that clay comprises a persistent and significant component of lake-bottom sediment deposited during summer. This apparently anomalous clay-settling behaviour can be attributed to production of fecal pellets found in both suspended sediment traps and bottom surficial deposits. The pellets, probably produced by pelagic copepods, are ovoidal with lengths typically ranging between 100 and 250 micro m and are composed of clay and silt. Measured settling rates in water at 5 C ranged between 80 and 400 m/day. Pellet production, then, accelerates the downward transfer of suspended detritus, resulting in deposition of much of the fine sediment that would otherwise escape the lake in interflows. This confuses patterns of bottom-sediment texture and mineralogy which would ordinarily be expected from settling behaviour of unpelletized suspensates.

268. SMITH, N.D., VENDL, M.A. and KENNEDY, S.K.
1982: Comparison of Sedimentation Regimes in Four Glacier-fed Lakes of Western Alberta; In: Research in Glacial, Glacio-fluvial and Glacio-lacustrine Systems, Proceedings of the 6th Guleph Symposium on Geomorphology 9-10 May, 1980, Editors R. Davison-Arnott, W. Nickling and B.D. Fahey, Geographical Publication No. 6, Department of Geography, University of Guelph, Geo Books Norwich, Geo Abstracts, Norwich, p. 203-238.

ABSTRACT:

Physical characteristics and sedimentation regimes of 4 river-dominated lakes fed by glacial meltwater are described and compared. The 4 lakes (Lower Waterfowl, Peyto, Hector, and Bow) are all located in intermontane valleys in the eastern Canadian Rocky Mountains.

Sedimentation patterns are strongly influenced by the type of initial mixing between inflow and lake water. Each of the 4 lakes is characterized by one of three kinds of inflow pattern: homopycnal, underflow, or overflow-interflow. Lower Waterfowl Lake is shallow and unstratified, and inflow carries uniformly low suspended sediment concentrations. Inflow mixing is homopycnal, and fine sediment is dispersed homogeneously through the lake, yielding negligible cross-lake and only weak downlake trends in sedimentation (grain size, deposition rates). In Peyto Lake, high inflowing suspended sediment concentrations result in predominantly underflows, and sediment transport and deposition patterns are largely controlled by bottom topography. Hector and Bow Lakes are both deep and thermally stratified during summer. Inflowing river water, carrying only moderate suspended loads, is less dense than the deep (hypolimnial) lake water and therefore enters the lakes as overflows and shallow interflows which are deflected rightward by the Coriolis effect. Pronounced crosslake as well as downlake sedimentation trends characterize both lakes.

Abundant fecal pellets of suspended-sediment-ingesting zooplankton, probably calanoid copepods, occur in Bow Lake. These may comprise an important, though previously unappreciated, mechanism in the dynamics of clay transport and deposition in similar lakes dominated by fine-grained clastic sediments.

269. SOPUCK, V.J., LEHTO, D.A.W., SCHREINER, B.T. and SMITH, J.W.J.
1980: Interpretation of Reconnaissance Lake Sediment Data in the Precambrian Shield Area, Saskatchewan; Saskatchewan Research Council, Report No. G78-10a, 53 p.

ABSTRACT:

Normalizing of metal contents in lake sediments is important due to variations in the physiochemical conditions and local bedrock chemistry from lake to lake. Normalization procedures for Cu, U, Zn, Ni and Co in lake sediments were established by detailed studies within the Maguire Lake area. In this report, the normalization procedures established in the Maguire Lake area are applied and tested for lake sediment metal data throughout the Saskatchewan portion of the Canadian Shield. The report is divided into three sections; metal partitioning among lake sediments components; regional controls on Cu, Co, Ni and Zn in lake sediments in the GSC-SGS survey area; regional controls on metal in lake sediments throughout the Saskatchewan Shield.

270. SOUTHARD, J.B., SMITH, N.D. and KUHNLE, R.A.
1984: Chutes and Lobes: Newly Identified Elements of Braiding in Shallow Gravelly Streams; In: Sedimentology of Gravels and Conglomerates, E.H. Koster and Steel, Editors, Canadian Society of Petroleum Geologists, Memoir 10, p. 51-59.

ABSTRACT:

In channel features here called chutes and lobes are dominant elements of braiding in the small gravel-bed outwash plain of Hilda Glacier, western Alberta, Canada. Observations of chutes and lobes were made in the field and in a laboratory flume arranged to represent a Froude scale model of the Hilda outwash plain but with steady rather than varying water discharge and sediment input rate. Chute-and-lobe behaviour was closely similar between field and laboratory.

Chutes are relatively deep, narrow channels lined with relatively fine sediment, through which coarse clasts move efficiently. A lobe forms at the downstream end of a chute by stalling and jamming of coarse clasts; once initiated, the lobe grows quickly by capturing more coarse clasts until it is several clasts thick and has a downstream slope so steep (up to about 12°) that incision begins, leading to deep dissection and development of one or more new chutes. Incision leaves lobe remnants as emergent gravel-bar topography.

Coarse, poorly sorted sediment together with very shallow flow depths seem to be the essential elements for development of chute-and-lobe behavior.

271. SPITZER, M.O.
1975: Preliminary Investigation of Suspended Sediment Transport in the Milk River; Internal Report, Water Survey of Canada, Inland Waters Directorate, Western Region, Environment Management Service, Environment Canada, Calgary, 44 p.

ABSTRACT:

This study is based on limited data but the information that has been gathered and analysed indicates that there is a significant amount of suspended sediment being transported and that the yield between the points where the St. Mary Canal spills into the Milk River and where it re-enters the United States increases nearly one-hundred fold. Also it indicates that the change in flow regime has greatly increased the suspended sediment yield. This additional material must be coming from the stream channel itself and therefore the rate of bank erosion has undoubtedly accelerated since the diversion was instituted. This accelerated erosion has probably contributed to an increased rate of bank sloughing and to changes to the meander patterns.

272. SPITZER, M.O.
1983: Sediment Station Cost-index Factor; Internal Report, Water Survey of Canada, Water Resources Branch, Inland Waters Directorate, Environment Canada, 34 p.

ABSTRACT:

This report contains two sections; a section on the data used and a section on the analysis of the data, with discussions and inclusions regarding these analyses. Cost comparisons and calculated costs for each station are presented.

273. STICH, H.F. and DUNN, B.P.
1980: The Carcinogenic Load of the Environment: Benzo(a) Pyrene in Sediments of Arctic Waters; Arctic, Vol. 33, No. 4, p. 807-814.

ABSTRACT:

Baseline levels of the chemical carcinogen benzo(a) pyrene were measured in arctic sediments. Levels were highest in samples from the Mackenzie River delta and adjacent areas of the Beaufort Sea. The distribution of carcinogen did not correspond to the location of inhabited areas - a natural rather than a man-made source for polycyclic aromatic hydrocarbons in arctic sediments is indicated.

274. STICHLING, W.
1973: Sediment Loads in Canadian Rivers; Proceedings of the 9th Canadian Hydrology Symposium on Fluvial Processes and Sedimentation, University of Alberta, Edmonton, MAY 8-9, p. 38-72.

ABSTRACT:

New development of water resources in Canada demands more and better information on hydrological and morphological processes in streams and watersheds.

This paper reviews the history of the sediment data collection program initiated in Canada in 1961, describes the latest equipment in use for measuring suspended sediment and bedload and outlines the methods used by the Water Survey of Canada for collecting and processing data. The paper compares sediment data collection technique in use in Canada with those of other countries, and also compares sedimentation conditions and sediment yield.

Because information on sediment in Canadian streams is limited, existing data were reviewed and expanded to a standard period by using existing records where these were available and estimating where records were not available. Sediment load was estimated for as many watersheds as possible by establishing a relationship between sediment load on the one hand and flow and other physiographical parameters on the other. The average suspended sediment concentration and the average suspended sediment yield per square mile per year were computed and tentative maps for these two parameters prepared.

275. STRANG, R.M.
1973: The Rate of Silt Accumulation in the Lower Peel River, Northwest Territories; Canadian Journal of Forestry Research, Vol. 3, p. 457-458.

ABSTRACT:

Estimates of the rates of silt accumulation in the lower Peel River were derived from excavated root systems of white spruce and from radiocarbon dating of buried detritus. They indicate that average annual accumulation is of the order of 1 cm.

276. TAMBURI CONSULTANTS
1985: An Analysis of Long-Term Sediment and Hydrometric Data at the Prince Albert Station; Report to the Sediment Survey Section, Water Resources Branch, Inland Waters Directorate, Environment Canada, 44 p.

ABSTRACT:

The long-term sediment records at the Prince Albert, Saskatchewan Station are analyzed. Local sediment sources are assessed as are long-term trends in the sediment data. A preliminary attempt was made to link upstream basin conditions with long-term trends in sediment yield. While the impacts of dams and diversions are not yet statistically significant, qualitative relation between basin wide trends in agricultural land use and long-term sediment yields appears possible. The dominant impact on long-term sediment production is flow generating mechanism (snowmelt versus convective).

The evaluation of the existing program with regard to its ability to obtain the correct data and provide relevant information has resulted in several significant recommendations contained in Section 13. These recommendations include comparison of the existing site with a site located upstream of Prince Albert and its urban outfalls. Modifications to the data collection program are also suggested but are dependent on the use of the information.

277. TELLER, J.T. and LAST, W.M.

1979: Post-glacial Sedimentation and History in Lake Manitoba; Report to the Department of Mines, Natural Resources, and Environment of the Province of Manitoba, 185 p.

ABSTRACT:

Fifty-one sediment cores were taken from the basin to provide the basis for an identification and a quantification of the physical and chemical changes that have occurred in and around the Lake Manitoba basin during the post-glacial period. Using these results, the authors have reconstructed the history of Lake Manitoba from it's glacial origin to the present.

278. TELLER, J.T. and LAST, W.M.

1982: Pedogenic Zones in Postglacial Sediment of Lake Manitoba, Canada; Earth Surface Processes and Landforms, Vol. 7, p. 367-379.

ABSTRACT:

The postglacial sediment record of Lake Manitoba is composed dominantly of silty clay to clayey silt with little variation in most physical, chemical, and mineralogical properties. Distinct in the sedimentary sequence of this large lake, however, are four zones that have a low moisture content, blocky to pelletal structure, and gleyed colour. All of these zones formed during the warmest and driest postglacial period in the region, 9500 to 4500 years ago. Although several possible hypotheses can be formulated regarding the origin of these zones including changes in sedimentation rate, clay mineralogy, lake chemistry, and depth of winter freezing, the most likely explanation is that they represent pedogenic horizons. Formation by pedogenesis during dry or extremely low water conditions is not mutually exclusive of the other hypotheses, and several are favoured by low water conditions.

279. THOMAS, D.J.

1980: Water Quality Measurements and Dredge Spoil Monitoring at McKinley Bay, N.W.T.; Report by Arctic Lab Ltd., Inuvik, N.W.T.

ABSRACT:

In accordance with the requirements of Dome Petroleum's Ocean Dumping permit, water quality measurements (dissolved oxygen, temperature, salinity and water transperancy) were conducted at 5 monitoring stations on four occasions at McKinley Bay, N.W.T., during 1980 dredging operations. No significant effects on the water quality of the parameters listed above could be related to dredging in McKinley Bay. The distributions of all measured parameters were generally similar for the station nearest to active dredging and the four background stations. Routine chemical analyses were also performed on dredge spoil samples. The heavy metal content was variable: except for Hg in one sample (290 mg/g sediment), all values fell within the range of values accepted for

average uncontaminated world coastal sediments. The exceptional mercury concentration was, however, still below the Ocean Dumping Control Act regulated limit of 750 mg Hg/g solid. Total organic carbon content and extractable oil and grease ranged from 0.09 to 8.65% and 45-2120 ppm by weight respectively. Oxygen uptake rates were low having a range of 0.031 to 0.268 mL 02/g sediment/day.

280. THOMAS, D.J., MACDONALD, R.W. and CORNFORD, A.B.
1985: Geochemical mass-balance calculations for the coastal Beaufort Sea, N.W.T., Canada; In: Contaminant Fluxes Through the Coastal Zone, No. 28, International Council for the Exploration of the Sea, 50 p.

ABSTRACT:

A geochemical mass balance approach was used to compare the natural flux of heavy metals and hydrocarbons from the Mackenzie River to the Beaufort Sea with the projected anthropogenic flux of heavy metals and hydrocarbons from proposed hydrocarbon production activities on the Beaufort Sea Shelf. Time scales and geographical scales for pollutants specific to the Mackenzie River/Beaufort Sea estuarine zone were set. The geochemical mass balance is a useful first step toward estimating possible effects of industrial activity in the coastal zone, it is within the framework of the physico-chemical estuary that bioavailability, bioaccumulation and ultimately, biological effect can be addressed.

The natural inputs to the Beaufort Sea are dominated by the Mackenzie River which delivers about 3.7×10^{11} m^3 discharge and 8.7×10^{7} m^3 particulates to the shelf each year. The flushing time for the shelf is estimated at four months; the residence time for 90-95% of the river-derived particulates is about 10 days. Consequently, most of the metals and hydrocarbons derived from the river are expected to settle out on the shelf. Atmospheric deposition and coastal erosion account for less than 5% of the natural flux of metals and hydrocarbons to the area.

Projected anthropogenic sources of heavy metals and hydrocarbons to the shelf include waste drilling muds, produced water, sewage, and combustion of fuel and trash; waste drilling muds are the predominant source. The estimates for the flux of anthropogenic inputs probably represent the "worst case" because oil industry projections for oil production and the pacing of Beaufort Sea Development have recently been adjusted downward.

On a regional basis and for the production rate projected for the year 2000 (approx. 48 000 m^3 oil (300 000 bbl) per day)), the ratio of anthropogenic to natural flux is estimated at 0.002 (Ni), 0.002 (Cu), 0.009 (Zn), 0.004 (Cd), 0.06 (Hg), 0.06 (Pb), 0.008 (Cr) and 3.3 (total hydrocarbons).

A three-dimensional dispersion model with an analytical solution to the diffusion equation was used to estimate sedimentary accumulation rates and dilution of dissolved components discharged at specific locations on the shelf. The results indicate that the

accumulation of metals and hydrocarbons in shelf sediments is likely to exceed natural rates of accumulation only within a 5-km zone around the discharge point. Taken into account were the large (approximately 10-fold) seasonal variation of Mackenzie River inputs; the influence of sea-ice which covers the Beaufort Sea for eight months of each year; the freshwater budget for the estuary; and the regional differences in natural sedimentation rates and particle transport.

281. THOMAS, J.F.J.
1957: Mackenzie River and Yukon River Drainage Basins in Canada, 1952-1953; Water Survey Report No. 8, Industrial Minerals Division, Mines Branch, Department of Mines and Technical Surveys, 78 p.

ABSTRACT:

This report, the eight in the series on the chemical quality of surface and municipal waters available for industrial and domestic use in Canada, covers the large area drained by the Mackenzie and Yukon Rivers and their tributaries. Chemical and physical parameters measured include pH, colour, turbidity, suspended sediments, dissolved solids and numerous individual ions.

282. TYWONIUK, N. and CASHMAN, M.A.
1973: Sediment distribution in river cross-sections; Proceedings of the 9th Canadian Hydrology Symposium on Fluvial Processes and Sedimentation, University of Alberta, Edmonton, May 8-9, 1973, p. 73-95.

ABSTRACT:

The variations is concentration and transport rate of a sediment-water mass in a river cross-section are the result of hydraulic variations in space and time. Moderately low and transversely uniform flow is generally characterized by low and transversely uniform sediment concentration. High and/or transversely irregular flows are similarily characterized by high and/or transversely irregular concentrations but with a different sediment-water ratio than for low flow. The dynamic processes which influence water transport in a river are also probable the most important influence on the distribution and transport of sediments in a river cross-section.

The variations in particle size distribution of sediments and in concentration and transport rate of a sediment-water mass in river cross-sections are illustrated herein. All available Canadian sediment survey data are used for this purpose. An assessment is made of the importance of spatial and time hydraulic variations as dispersing mechanisms under a wide range of natural flow conditions. Finally, theoretical expressions describing sediment-water transport phenomenon are verified and conclusions are drawn with respect to the applicability of these expressions to Canadian conditions.

283. TYWONIUK, N. and LUTHER, W.M.
1968: Sedimentation Study of the Qu'Appelle Drainage Basin; Internal Report, Inland Waters Branch, Department of Energy, Mines and Resources, Calgary, 61 p.

ABSTRACT:

Estimates of the total load discharge for eighteen Qu'Appelle River tributaries were made as follows:

1. the Modified Einstein Method, Meyer-Peter and Muller Method, and the Colby Method were used to estimate total load discharges for nine tributaries.

2. 'Annual yield - area' and 'maximum daily yield - area' correlations were obtained for the 1:2, 1:10, 1:25 and 1:50 flood hydrographs. Yield estimates for nine additional tributaries were made on the basis of the correlations.

A field survey was carried out in September 1968 to obtain bed and deposited material samples for nine tributaries and for the Qu'Appelle River and Valley. The laboratory analysis results are included.

The methods of analysis used in determining tributary sediment yields provide reasonable estimates for preliminary planning and design. A more detailed study is recommended for final design purposes.

284. VAN DER GIESSEN, N.
1966: Observations on Gravel Transport in Four Rivers in Western Alberta; Unpublished M.Sc. Thesis, Department of Civil Engineering, University of Alberta, Edmonton, 212 p.

ABSTRACT:

Colored river-bed stones were used to study initiation of motion and the distance of transport of bed material in two streams of different character and discharges. Concurrently, various modifications of recent methods of estimating the grain size distributions of coarse alluvial sediments were tested. Regime data of the streams and of two others were collected. The results were analysed in terms of tractive force theory and of the regime-slope analysis chart of regime theory; the relevance of the behavior of the colored stones was considered.

The larger colored stones of the channel bed material appear practical as indicators of incipient motion at different stages of flow. Approximate log-normality was found in groups of colored rocks after transport within a limiting distance. The sampling of bed-material by the "stretched-tape" method proved preferable over the other methods tested because of consistency of results and ease and speed of sampling. The choice of sampling method was found to have considerable influence on the estimated median size of the

bed-material. However, the use to which the estimated size is put in practice, (i.e. roughness calculations in flow formulas), makes the difference in the sizes of secondary importance there. The size of bed-material relative to depth was large, and zero bed-factor was found to vary with relative bed-material size in rather the manner predicted by the experiments of Bhattacharya (1960) and Qureshi (1962) with 1.7 mm "gravel" in a laboratory flume; scatter of plotted points prevented a definite conclusion on this matter. The phase of flow-cum-transport was that in which regime equations are stated to be inapplicable without empirical modification. Both tractive force and regime methods were found useful for comparing the results of the surveys with the behavior of rivers in general.

285. Van EVERDINGEN, R.O.
1968: Diefenbaker Lake, Effects of Bank Erosion on Storage Capacity; Department of Energy, Mines and Resources, Inland Water Branch, Technical Bulletin No. 10, 21 p.

ABSTRACT:

Accelerated erosion of valley slopes by waves, as a consequence of the creation of Diefenbaker Lake, will result in a decrease in total storage capacity of that reservoir, an increase in usable storage and some increase in annual evaporation.

286. VELDMAN, W.M.
1969: Shoreline Processes on Lake Winnipeg; Unpublished M.Sc. Thesis, Department of Civil Engineering, University of Manitoba, Winnipeg, 87 p. + Appendices.

ABSTRACT:

Shoreline recession is an ever present problem on Lake Winnipeg and is accentuated during storm periods and high lake levels. With the ever-increasing value of property along the shoreline, this recession can cause serious damage.

Before any works are constructed to halt shoreline recession, it is necessary to understand the littoral processes acting upon the shoreline and how these processes are related to sources and losses of material, natural and man-made littoral drift barriers, and fluctuations in the lake levels. This thesis gives a general analysis of the processes acting upon the shoreline from Riverton to Sans Souci on the west and from Elk Island to Balsam Bay on the east. Furthermore a detailed study of the shoreline at Winnipeg Beach was made with the aid of a model.

The author fully realizes that this study is only preliminary in nature but hopes that it will give some insight into the problems of shoreline recession and that it will stimulate thoughts, discussions and further studies into this challenging problem.

287. VENDL, M.A.
1978: Sedimentation in Glacier-fed Peyto Lake, Alberta; M.Sc. Thesis, University of Illinois at Chicago Circle, Chicago, Illinois, 96 p.

ABSTRACT:

Peyto Lake, located in Banff National Park, Alberta, is 2-1/2 km long, 3/4 km wide, and has a maximum depth of 49 m. The lake is fed by Peyto Glacier outwash which is building a classic Gilbert-type delta into the lake. A subaqueous sill partially bisects the lake basin into separate but contiguous upper and lower basins.

Outwash discharges and suspended sediment concentrations vary widely with weather conditions. During the summer of 1976, measured suspended sediment concentrations averaged 720 mg/l but ranged from 138-2160 mg/l. Because of the high sediment concentrations, inflow usually enters the lake as underflows. This phenomenon is enhanced by the nearly isothermal character of the lake. Underflow velocities, up to 13 cm/s, pulsate quickly and vary with changes in stream discharge. Calculated underflow velocities are generally higher than observed velocities. This difference could be due to an underestimation of the frictional coefficients at the bottom and at the fluid-fluid interface, and/or uncertainty in location of velocity stations. Calculations of frictional coefficients using variables measured in Peyto Lake give values of 0.22 and 0.31. During periods of low discharge the outwash stream may enter the lake as overflows or shallow interflows. Mean sedimentation rates ranged from 160 mg/cm^2/day near the delta to 5 mg/cm^2/day at ths distal end during the summer of 1976.

Data from sediment traps, transmissivity surveys, drogues, and grain size analysis of cores show that lake floor sediment distribution is controlled principally by bottom topography; underflows move across low areas of the lake bottom and pass from the upper to the lower basin around the subaqueous sill.

Most bottom sediment cores are well laminated, but only rarely can classic annual varves be recognized. Most laminations appear to result from inflow variations caused by short-term weather changes.

288. VITKIN, N. and PENNER, F.
1979: Review of Suspended Sediment Sampling Program in Manitoba; Internal Report, Water Resources Branch, Manitoba Department of Natural Resources, Winnipeg, 21 p. + Figures.

ABSTRACT:

This report examines the value of additional years of record at some stations to determine if they should be allowed to function at their present status or if they should be discontinued. The report allows suggest a number of new station that should be established.

289. **WAGEMANN**, R., BRUNSKILL, G.J. and GRAHAM, B.W.
1977: Composition and Reactivity of Some River Sediments from the Mackenzie Valley, N.W.T., Canada; Environmental Geology, Vol. 1, No. 6, p. 349-358.

ABSTRACT:

Sediments from the Mackenzie Valley - two suspended and one river bottom - were analyzed for major and minor elements, mineralogy particle size, and ability to release trace metals when subjected to mild leaching.

Copper and zinc in suspended sediments and cadmium in bottom sediment occurred largely (70 to 84 percent for Cu, 82 to 98 percent for Zn, 75 to 81 percent for Cd) in a form that could not easily be separated from the sediments by 0.1M HCl and EDTA solutions. Cadmium was present in suspended sediments in low concentrations and was present totally in sorbed leachable from iron, mangenase, cobalt and chromium were separable from the particulate phase by mild leaching. It was found that approximately 70 hours were required for an apparent steady state concentration to be attained in such leachings.

Reaction of these sediments with Beaufort Sea water (salinity 22.3 parts per thousand) indicated that both iron and manganese were released from sediments to sea water to a very small degree. Copper, lead, and zinc, however, were absorbed by sediments from sea water.

290. **WAGEMANN**, R., SNOW, N.B., ROSENBERG, D.M. and LUTZ, A.
1978: Arsenic in Sediments, Water and Aquatic Biota from Lakes in the Vicinity of Yellowknife, Northwest Territories, Canada; Archives of Environmental Contamination and Toxicology, Vol. 7, p. 169-191.

ABSTRACT:

Arsenic concentrations were measured in aquatic invertebrates, macrophytes, sediments, and water of lakes in the vicinity of Yellowknife (N.W.T.), Canada... The arsenic concentration in invertebrates varied with sampling time, place, and taxon. Arsenic concentration factors were calculated, and found to decrease with increasing concentration of arsenic in ecosystem components of the lake. No evidence was found for biomagnification of arsenic through ascending trophic levels. In high-arsenic lakes herbivores had the highest arsenic concentrations, and omnivores the lowest. Pelecypoda, Ephemeroptera, Amphipoda, and Hirudinea were conspicuously absent from high-arsenic lakes. These particular organisms may be more susceptible to the effects of arsenic than others.

291. **WALLIS, P.M.**
1981: The Uptake of Dissolved Organic Matter in Groundwater by Stream Sediments - A Case Study; In: Perspectives in Running Water Ecology, M.A. Lock and D.D. Williams, Editors, Plenum, New York, p. 97-111.

ABSTRACT:

Dissolved organic matter (DOM) is the most important source of organic energy in headwater streams. Groundwater is the major component of stream flow, and its DOM contributes large amounts of energy to stream production. Nutrient concentration in the stream is higher than in groundwater, so the transition from ground to stream water leads to more favourable conditions for microbial growth and metabolism. Field uptake experiments, and 13C studies, were carried out in the Marmot Basin, in the Kananaskis Valley near Calgary, Alberta. Sediment samples for laboratory experiments were taken from Laurel Creek near the University of Waterloo. The average uptake of groundwater DOM in the Marmot Basin was calculated to be 207 mg per m per h. This high level of uptake suggests that stream bacteria can remove higher portions of the dissolved organic load than groundwater bacteria. The 13C content of streamwaters from the mouth of the Middle Creek Tributary is less than that of the source spring. This suggests that additional organic matter which has not been so efficiently degraded has entered the stream between the two sites. The decrease in concentration of DOM in groundwaters as they percolate into the stream through the sediments indicates that energy is made available to sessile microorganisms from the source. This organic matter is mobilized from the humud layer by infiltrating precipitation and carried through the unsaturated and saturated groundwater zones. Despite the high uptake rates found during field studies, DOM in groundwater must still be considered to be refractory in nature.

292. **WANKIEWICZ, P.M.**
1979: Sedimentation in Sunwapta Lake, Jasper National Park, Alberta; Unpublished M.Sc. Thesis, University of Alberta, Edmonton, 258 p.

ABSTRACT:

Sunwapta Lake is a small proglacial lake adjacent to the retreating Athabasca Glacier (Columbia Icefield, Jasper National Park). Discharge in the Sunwapta River has been monitored since 1948, and work on sedimentation in the lake has been carried out in previous years. During the melt season of 1975, suspended sediment distribution and deposition were studied, based on samples of suspended and dissolved sediment from the inflow stream and the lake, sediment pan samples from the lake bed, discharge measurements from the inflow and outflow streams, temperature records, and core samples taken with a gravity corer. From the data, sediment input, patterns and processes of sediment distribution (by overflow, interflow, and underflow) in the lake and rates of sedimentation were computed. The results and the core samples were compared with results and cores obtained in previous research. Interpretation of changes in Sunwapta Lake sedimentation may be useful in studies of Pleistocene, as well as modern, proglacial lakes.

293. WARDLE, S.
1978: Chemical Analytical Methodology for Nutrient Analysis of Sediment Cores of Baptiste Lake, Lake Isle, and Lac Ste. Anne; Internal Report, Pollution Control, Environmental Protection Service, Alberta Environment, Edmonton, 63 p.

ABSTRACT:

Methods were successfully developed for the analysis of the nutrient parameters, nitrogen (ammonia, nitrate, nitrite, Kjeldahl),m phosphorus (total, inorganic) and carbon (total, organic) in sediments. Core samples of 7.5 m, 6.5 m and 2.0 m were obtained from Baptiste Lake, Lake Isle and Lac Ste. Anne respectively, in March 1977. The cores were frozen and fractionated at 5 cm intervals prior to freeze-drying. Analysis of the core samples for the above parameters was subsequently carried out. The results from each of these lakes were tabulated and concentrations versus depth of core presented graphically.

294. WARNER, L.A.
1979: Interim Compilation of 1977 Suspended Sediment Data for the AOSERP Study Area; Report Prepared for the Alberta Oil Sands Environmental Research Program, Project WS 1.1, 47 p.

ABSTRACT:

This compilation report contains all the available 1977 suspended sediment concentration and particle size data collected in the Alberta Oil Sands Environmental Research Program study area.

295. WARNER, L.A. and SPITZER, M.O.
1979: Interim Compilation of 1976 Suspended Sediment Data for the AOSERP Study Area; Report Prepared for the Alberta Oil Sands Environmental Research Program, Project HY 1.3, 59 p.

ABSTRACT:

This compilation report contains all the available 1976 suspended sediment concentration and particle size data collected in the Alberta Oil Sands Environmental Research Program study area.

296. WAY, J.G.
1980: A Review of the Classification of Sediment Quantity Survey Stations in the Western and Northern Region; Internal Report, Environment Canada, Western and Northern Region, Inland Waters Directorate, Winnipeg, 15 p. + Appendices.

ABSTRACT:

The purpose of this report is to review the reports prepared by the WSC responsibility centres on the proposed classification of sediment program stations, and investigate whether or not a consistent approach has been taken. This review was initiated at the request of the Regional Director of IWD, W&N Region. The terms of reference for this consolidated report of the input provided by the three WSC responsibility centres is included in this report as Appendix A. This summary report serves as a first step in preparing for action as detailed in Section E of the IWD Directors Committee Policy Decisions Relating to the WRB Sediment Survey Program. Appendix B contains the policy decisions on the WRB sediment survey program by the IWD directors.

297. **WAY, J.G.** and THORNE, G.A.
1977: Reconnaissance of Polar Gas Route River Crossings in Keewatin District, N.W.T., Interim Report (FP-1-76-3) Hydrologic Regimes Freshwater Project No. 1, Environment Canada, Inland Waters Directorate, Water Survey of Canada, Western and Northern Region, 143 p.

ABSTRACT:

This report summarizes the work carried out during 1976 by the FP-1-76-3 Project of the Hydrologic Regimes component of the Freshwater Program of the Arctic Islands Pipeline Program. The objective of this project was to obtain an overview of hydrology along the pipeline corridor from Churchill to Spence Bay, in order to provide data for an adequate assessment of the proponent's application as it concerns river crossings. To achieve the objective, broad spatial coverage of hydrologic events through a "quick look" reconnaissance was performed, similar to that of Wedel and Way (1976).

Due to the vastness of the geographic area involved, the large number of lakes and rivers found within it, and the fact that studies of hydrologic events are time-dependent, additional information is required before quantitative assessments can be made. However, an attempt has been made to relate hydrologic, fluvio-morphometric and climatic data to support subjective approximations of hydrologic parameters.

Appended to this report is a survey equipment, listing a detailed stream catalogue and a listing of water quality parameters analyzed by the Water Quality Branch, Inland Waters Directorate, Western and Northern Region. Within the reconnaissance area - and as part of the Freshwater Program - three separate reports have been submitted by the Glaciology Division of the Inland Waters Directorate, Environment Canada, dealing with hydrologic regimes in the district of keewatin. For information purposes they are:

FP-1-76-4A: Snowmelt Runoff, Airplane Lake Basin, Baker Lake, N.W.T., June 1976, J.P. Chyurlia.

FP-1-76-4B: Spring Break-up Observations at Polar Gas Proposed Pipeline Crossing Sites of Keewatin Rivers, 1976 - A Progress Report, B.J. Grey.

FP-1-76-4C: 1976 Aerial Photography by D.A. Sherstone.

Two major recommendations result from this year's investigations: one being the need for a user-oriented centralized hydrologic data bank, which was originally proposed by Wedel and Way (1976); and the other the need for the establishment of a continuous hydrologic and fluvio-morphometric network rather than a hydrometric network alone.

298. WAY, J.G. and THORNE, G.A.
1977: Reconnaissance of Pipeline River Crossings - Keewatin District; Preliminary Report, 1977, Environmental-Social Program, Northern Pipelines, 145 p.

ABSTRACT:

This report summarizes the work carried out during 1976 by the FP-1-76-3 Project of the Hydrologic Regimes component of the Freshwater Program of the Arctic Islands Pipeline Program. The objective of this project was to obtain an overview of hydrology along the pipeline corridor from Churchill to Spence Bay, in order to provide data for an adequate assessment of the proponent's application as it concerns river crossings. To achieve the objective, broad spatial coverage of hydrologic events through a "quick look" reconnaissance was performed, similar to that of Wedel and Way (1976).

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299. WAYLEN, P.R.
1976: Suspended Sediment in a Small High Arctic Basin; Unpublished M.A. Thesis, McMaster University, Hamilton, 81 p.

ABSTRACT:

The concept of suspended sediment, its role in fluvial geomorphology, transport, measurement and modelling are dealt within Chapter 1 in the form of a literature review. Chapter 2 consists of a brief review of the environment of the "Schei" river basin in the Canadian Arctic. Chapter 3 deals with data obtained from the basin in the summer of 1975. The principal methodology used is that of the rating curves... A physical explanation for several phenomena in the series of readings is suggested. Finally a possible alternative to avoid the difficulties of the rating curve method is suggested.

300. WEDEL, J.H.
1978: Hydrologic Investigations Along the Arctic Islands Pipeline Route; Report, Environmental-Social Program, Northern Pipelines, 104 p.

ABSTRACT:

An overview of hydrologic activity in the region from Melville Island to northern Manitoba was obtained in three field seasons. This information was gathered from a position of independence in order to assess the application of Polar Gas to construct a natural gas pipeline through the region. Some understanding of fluvial and associated geomorphic processes was obtained. Specific processes studied were streamflow, ice-runs and icings, and sediment movement. Assessments of fluvial landforms were made in the field and from aerial photography. The effects of arctic mass-wasting processes on valley walls, valley bottoms and on river channels was documented, mostly in a qualitative sense. It was found that the spring freshet generated the dominant annual flood although the record rainstorm of August 1960 in the islands may have generated flows greater than those from snowmelt. On the Hayes and Murchison Rivers, high late-summer runoff is also common. Two high-sediment-yield regions were defined: the Melville-Bathurst region and the Rasmussen Lowland south from Spence Bay - the former a zone of extensive in situ weathering of shales, siltstones and fine-grained sandstones, and the latter an extensive marine plain. Disturbance of fine-grained sub-channel materials will adversely affect the aquatic biome in the clear-water systems of the Keewatin

District and those rivers farther north which have deep lakes - particularly the Union River, a number of systems near Bellot Strait and the river-lake regimes around Spence Bay. Thermal erosion and thermokarst are two heat-related processes that could lead to severe gullying and pipeline instabilities during construction over sensitive terrain. Berm or roadway construction on the right-of-way and low gas temperatures in the operating phase will create a rise in the permafrost table and impede the movement of near-surface groundwater on slopes. Ponding and erosional problems may result. In Keewatin streams which maintain a low volume of flow in midwinter, icing may result if channel surface temperatures drop below 0°C from the chilled pipeline, thus further restricting the passageway. Insufficient data exists to make accurate predictions of flood magnitudes and their recurrence intervals for this region.

301. WEDEL, J.H. and WAY, J.G.
1976: Eastern Arctic Islands Pipeline Project, Spence Bay to Sabine Peninsula; Interim Report, Hydrologic Regimes Freshwater Project No. 1, Environment Canada, Inland Waters Directorate, Water Survey of Canada, Western and Northern Region, 327 p.

ABSTRACT:

This report summarizes the work carried out during 1975 by the Hydrologic Regimes component of the Freshwater Program of the Arctic Islands Pipelines Study Group, under the auspices of the Environmental-Social Program of the Department of Indian Affairs and Northern Development. The objective of the Hydrologic Regimes component (FP-1) was to obtain an overview of hydrology along the pipeline corridor north of Spencer Bay, in order to provide data for an adequate assessment of the proponent's application. Because of the paucity of knowledge concerning hydrologic processes and events in the study area and because of the uncertainties of pipeline routing, it was deemed necessary in 1975 to collect data over a broad geographic base. This spatial distribution is Phase One of FP-1's study and will be related to Phase Two, planned for 1976 (the chronologic distribution of hydrologic events).

As fluvio-morphometric concerns are inextricably linked to hydrologic parameters, they must become part of any data set. For this report, it was possible to make only qualitative assessments of these concerns as a minimum of field time was spent on site in order to provide extensive geographic coverage. In any case, attempts have been made to relate the hydrologic and geomorphic data to pipeline concerns, both environmental and those of engineering design. The subjective conclusions and qualitative assessments made in this interim report will no doubt be revised as more data becomes available.

Appended to this report are a survey equipment listing, a detailed catalogue, and an FP-1 funded report on water quality parameters from the Water Quality Branch, Environment Canada, Winnipeg. Because of time constraints, snow reports from Glaciology Division will appear as independent papers.

One major recommendation that the authors of this report would like to make is the need for the establishment of a user-oriented centralized hydrologic data bank. Since the greatest volume of hydrologic data for the study area is in scientific research papers and many times is only peripheral information necessary to the development of the papers' main theme, a centralized data bank would perform a useful function. The writers feel the establishment of a data bank could best be accomplished by the incorporation of research data from universities and other in-government agencies and departments into the central data banks of the Inland Waters Directorate, Environment Canada.

302. WEDEL, J.H., THORNE, G.A., BARACOS, P.C.
1977: Site-Intensive Hydrologic Study of a Small Catchment on Bathurst Island; Interim Report, 1977, Hydrologic Regimes, Freshwater Project No. 1, Inland Waters Directorate, Water Survey of Canada, Western and Northern Region, 124 p.

SUMMARY:

The Snowbird Creek study lies in the eastern segment of a surficially active zone of loosely consolidated sandstones and other sedimentaries mantled by a regolith of sandy silt which is susceptible, in the High Arctic environment, to considerable mass movement and fluvial erosion.

Other investigators of arctic hydrology (Holecek and Vosahlo, 1975; Cogley and McCann, 1975; Rannie, 1976) have derived basin water budgets, one common method of assessing the hydrologic parameters of small catchments. Their research suggests that meteorological parameters - most notably snow precipitation data and the amount of snow available for melt in June or July of the succeeding summer - are the principal reasons for imbalance in their budgets. Since our goal was similar, the study group made snow surveys prior to runoff in June. Mean value for water content of snow on the ground on June 19 was 117 millimetres. Areal snow regression was computed from Landsat imagery, two sets of high and low level aerial photography, a second snow survey, and by chronologically sequenced ground photos. Linear regressions on meteorological data related to snowmelt runoff generated a moderately successful, emprical model.

Rainfall was light - a total of 19 millimetres (mm) for the period starting May 29 and ending August 28. Calculated runoff for Snowbird Creek was 156 mm, and for Whitebear Creek,* 136 mm. Analyses of the discharge hydrographs indicates some groundwater contribution to runoff from the active layer, or from meltwater from deep snowbeds for the period July 24 to July 30. It appears likely that condensation contributes measurable input into the water budget. Calculations for condensation on snow surfaces alone indicate 4 mm of input as a mean value over the basin. Snowfall from June 19 to August 30 represents an ungauged precipitation value.

For pipeline investigations it is apparent that a satisfactory computation of surface runoff is only an input into the measurement of sediment transport, erosion, and degradation-aggradation. Accordingly, data was assembled for bed material, suspended and dissolved sediment discharge for the main site on Snowbird Creek and the tributary site on Whitebear Creek. For Snowbird, the total load was computed as 1,983 tonnes/year, and for Whitebear as 244 tonnes/year. Hysteresis in the plot of sediment concentrations was apparent - the heaviest concentrations occurring with the first substantial runoff on July 4. Maximum concentrations measured were in the order of 1,300 parts per million (ppm) and 1,100 ppm for Snowbird and Whitebear respectively. Deposition of sediments in the main channel by early rill and gully flow.

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*Locally named by investigators during summer of 1976.

303. WELCH, D.M.

1973: Channel Form and Bank Erosion, Red River, Manitoba; Proceedings of the 9th Canadian Hydrology Symposium on Fluvial Processes and Sedimentation, University of Alberta, Edmonton, May 8-9, p. 284-293.

ABSTRACT:

Active erosion on the inside of meanders, and abandoned meander bluffs, indicate that the Red River near Winnipeg is becoming straighter. Analysis of detailed hydrographic surveys from Emerson to Lake Winnipeg also indicates straightening. These phenomena may be explained by isostatic rebound toward the north, by increasing roughness due to changing bed materials, or alternatively the channel may be distorted by rotational slides on meander bluffs which enter the channel faster than stream corrosion can remove them.

Local variations of bank and meander geometry seem related to changes of absolute gradient, the entry of the Assiniboine River, and water level control at Lockport.

304. WIEBE, K.

1971: Edward Creek: Estimation of Reservoir Sedimentation for a 100-Year Flood; Internal Report, Sediment Survey Section, Water Resources Branch, Inland Waters Directorate, Environment Canada, Ottawa, 11 p.

ABSTRACT:

The author estimates the reservoir storage lost due to sedimentation during a 100-year flood and during a probable maximum flood.

305. WIEBE, K. and DRENNAN, L.
1974: Sedimentation in Reservoirs; Proceedings of the 9th Canadian Hydrology Symposium, on Fluvial Processes and Sedimentation, Edmonton, May 8-9, 1973, p. 538-579.

ABSTRACT:

The construction of dams and impoundment of waters give rise to the problem of sedimentation. The magnitude of the problem depends mainly on the rate of sedimentation and can vary considerably.

A means to minimize the rate of reservoir sedimentation must be found to ensure that the water and power demands of a steadily increasing population will continue to be met. To obtain a satisfactory solution, the principal modes of sediment deposition in reservoirs and their relation to sediment supply, reservoir capacity and operating procedures must be understood.

This paper provides a detailed explanation of the above interrelated processes. Also included is an evaluation of sedimentation in Canadian reservoirs. Specific reference is made to Lake Diefenbaker with an outline of survey methods and a complete evaluation of the data obtained to date.

Finally, guidelines are proposed for consideration in the planning of future projects with potential problem areas being emphasized.

306. WIGHAM, J.M. and STOLTE, W.J.
1973: Sediment Yield Estimates from an Index of Potential Sediment Production; Proceedings of the 9th Canadian Hydrology Symposium on Fluvial Processes and Sedimentation, University of Alberta, Edmonton, May 8-9, p. 208-214.

ABSTRACT:

A method of estimating the sediment yield, for catchments on the canadian prairies, is presented. The method involves evaluation of a potential sediment production index from watershed characteristics using a modified form of the universal soil loss equation. Multiple regression techniques confirmed the validity of the form of the equation and of the variables used in the equation. The index is related to sediment yield estimates obtained by other methods and through comparisons with some sediment flow measurements. The correlation of the index to the sediment flow data was good; however, only a few catchments could be analyzed. Confirmation of the index as an accurate measure of sediment yield therefore must await further information on measured sediment flows. It would appear to have some immediate usefulness, however, for preliminary designs and for use on ungauged catchments.

307. WILSON, C.D.
1973: Sedimentation Study of the Moose Jaw River, 1973; Internal Report, Water Survey of Canada, Environment Canada, Regina, 13 p.

ABSTRACT:

Based upon limited field data, the objective of this study was to: 1. Arrive at an estimate of sediment yield for flood frequencies of 1:2, 1:10, 1:25 and 1:50 at the following hydrometric gauging stations: (a) Moose Jaw River above Thunder Creek, (b) Moose Jaw River near Burdick. 2. Estimate the trap efficiencies of the reservoir created by the CPR Dam in the City of Moose Jaw and the proposed upper site and lower site reservoirs located on the main stem Moose Jaw River above the City of Moose Jaw. Because of the limited sediment data available, the assumption that bedload is small compared to total load and the uncertainty of the slope and/or position of the discharge versus sediment discharge curves for hydrometric gauging stations, Moose Jaw River above Thunder Creek and Moose Jaw River near Burdick, all values arrived at in this report should be classified as rough estimates. The increase in capacity of 3.6 acre-feet between 1966 and 1972 of the reservoir created by the CPR Dam may not be accurate due to the assumptions made and the method used in determining volume change. If one accepts this value, it would suggest that little siltation or scour occurs in the reach considered at that the channel is relatively stable considering man-made changes that have occurred.

308. WILSON CREEK HEADWATER FLOOD AND EROSION CONTROL COMMITTEE
1983: Summary Report of the Wilson Creek Experimental Watershed Study, 1957-1982; Unpublished Report, Winnipeg, 18 p.

ABSTRACT:

Twenty-five years ago, the Wilson Creek Watershed was selected as a study site for runoff and erosion control on streams that rise on the steep Manitoba escarpment. In the ensuing period, meteorological and hydrologic data were gathered and the watershed was studied to determine the runoff characteristics of an escarpmental headwater basin. Research studies considering the hydrologic processes in detail; flood frequency, rainfall frequency, groundwater movement, sediment transport and snowmelt characteristics were published as graduate theses in Geography, Earth Sciences and Civil Engineering. Two headwater reservoirs and numerous channel protection works were constructed. The headwater reservoirs were found to reduce peak flood flows by 5 to 15 percent. This was insufficient to significantly reduce sediment transport or flood damage in the watershed. Channel protection works were destroyed during the maximum flood on record which occurred in September, 1975 following a 250 mm (9.84 inch) storm rainfall. Land use studies in the alluvial fan and farmlands below the escarpment indicated that a large portion of the sediment which regularly obstructs the agricultural drainage network consists of resuspended sediments from the fan area. In 1980, two experimental rockfill energy dissipation dams were constructed in the alluvial fan channel to control this recent and dominant source of sediments.

It is recommended that further headwater studies be discontinued with the exception of monitoring rainfall and flood flows which are necessary to evaluate the performance of the energy dissipation dams constructed on the alluvial fan, and to provide flood potential warnings for the flood prone areas along the base of the escarpment.

NOTE: Annual reports have been published, describing the work performed and the expenditures made during each fiscal year.

309. **WOLOWICH**, E.A. and TAMBURI, A.J.
1985: Sediment Dynamics on the Assiniboine River; Proceedings on the 7th Canadian Hydrotechnical Conference, 27-31 May, 1985, Saskatoon, Saskatchewan, p. 127-147.

ABSTRACT:

Sediment dynamics at a station and station to station are assessed on the Assiniboine River of Manitoba. Water Survey of Canada sediment and hydraulic data were analyzed yielding sediment parameter relationships. Using these relationships, a comparison of measured data with K-factor and stage-discarge estimated data was carried out. K-factor data proved to be inferior to measured data. The effects of the Portage Diversion works on the Assiniboine River were also studied. Parameter relationships before and after the construction of the diversion works indicate a change in channel regime downstream of the diversion at Portage la Prairie.

An intensive on site survey was carried out to identify various physical features that influence the total sediment load, such as landslides, active springs, and channel geology. It was found that much of the Assiniboine's bed is armored and depleted of sediment. Sediment contribution is chiefly a result of the numerous landslides and ground water springs throughout in a steady state but rather by pulses in the form of sand waves which approach the flow depth in height.

Total loads at Water Survey of Canada stations are computed using the Ackers-White sediment transport function (1973). These loads were considerably more than those measured by Water Survey. This was also confirmed using the Colby (1964) method of sediment transport, thereby confirming that the stream is armored along much of its reach and transporting less than an equilibrium sediment load. The existing bed material load is thus supply rather than hydraulics determined.

310. **WYLDMAN**, E.C. and POLIQUIN, W.H.
1973: Effects of Oilfield Development on Sedimentation in the Swan Hills, Alberta; Proceedings of the 9th Canadian Hydrology Symposium on Fluvial Processes and Sedimentation. University of Alberta, Edmonton, May 8-9, p. 192-207.

ABSTRACT:

This discussion paper briefly describes the extremely high erosion and sedimentation resulting from intensive oilfield development in a forested area having erosive parent material, shallow soils, steep terrain and high precipitation. Land use effects have also resulted from timber harvesting, wildfire, highway construction and floods.

Quantitative data are presented from erosion-runoff plots and from a suspended sediment monitoring program on the Swan River. Precipitation data are shown in relation to runoff and sediment production.

The effects of land use upon water quality, stream and l;ake fisheries, roads and structures, and flood peaks will be discussed and shown graphically.

311. YUZYK, T.R.
1978: Aspects Concerning and Sedimentation of Avonlea Reservoir; Internal Report, Sediment Survey Section, Water Resources Branch, Inland Waters Directorate, Environment Canada, 46 p. + 2 Appendices.

ABSTRACT:

Sediment filling of Avonlea reservoir has been proceeding at a rate of 31.5 dam^3/yr (25.5 acre-ft./yr) based on information obtained from the volumetric surveys completed in 1974 compared with those at construction. Under past flow conditions the reservoir will have a useful life expectancy in the order of 90 years.

The concern initially that the reservoir was losing storage capacity at a faster rate was due to the fact that the original reservoir capacity was incorrectly determined. Results from this study show that sedimentation rates for Avonlea reservoir are normal for its environmental and drainage basin characteristics.

A review of equations and formulae designed to predict sediment yields for environments such as Avonlea showed them at variance with the value obtained from this study of 15.8 $tonnes/km^2/yr$.

312. YUZYK, T.R.
1983: Changes in Lake Diefenbaker's Storage Capacity Due to Sedimentation, 1966-1978; Unpublished M.A. Thesis, Department of Geography, University of Ottawa, Ottawa, Ontario, 121 p. + Appendices.

ABSTRACT:

Based on hydrometric station data, the South Saskatchewan River transports on average 6 000 000 tonnes of sediment into Lake Diefenbaker, per year. But because of the enormous size of the reservoir, the sedimentation rate is low. Hydrographic surveys

conducted between 1966 and 1978 indicate that 1.4% of the total reservoir volume has been depleted due to sedimentation. The live storage was reduced by 1.5%, while the dead storage by 1.3% of its capacity. Therefore, the impact on reservoir operations is minimal. Most of the sediment load transported was deposited between Range 32 and Range 25, the drawdown reach. The sand portion of the load settled out of suspension within this reach while beyond Range 21 mostly clays were left in suspension. The large water level drawdown inhibited the development of a classical delta structure. Swift Current Creek's sediment contribution was negligible, and locally less significant than the bank material contribution. The bank material contribution accounted for 0.5% of the 1.5% loss in the total live storage.

313. YUZYK, T.R.
1983: Lake Diefenbaker, Saskatchewan: A Case Study of Reservoir Sedimentation; Internal Report, Sediment Survey Section, Water Resources Branch, Inland Waters Directorate, Environment Canada, 118 p.

ABSTRACT:

In 1965 a field survey program was implemented to monitor general sedimentation patterns, delta formation and bank erosion in what was to become Lake Diefenbaker. After fifteen years of data collection it was agreed that this program should be reviewed. The review focussed on two principal areas: to compile, analyse and interpret all the data collected from Lake Diefenbaker and document the sedimentation patterns; to evaluate the existing data collection program and identify changes required to ensure an effective and efficient program. Sedimentation has not significantly affected the reservoir operation, since only 1.4% of the total reservoir capacity has been lost between 1966-1980. Delta formation was determined to be affected by a low original bed slope, large water level drawdown and reduced sediment loadings in the latter years. The bed slopes indicate that the delta structure has yet to reach equilibrium. Bed material sampling showed that deposited densities were considerably lower than empirically derived values, which greatly affected the deposited load estimates. Recommendations were made based on the findings of this report.

314. YUZYK, T.R.
1984: Reservoir Sedimentation Studies in Canada; Internal Report, Sediment Survey Section, Water Resources Branch, Inland Waters Directorate, Environment Canada, 33 p.

ABSTRACT:

The report contains an overview of reservoir sedimentation and the techniques used to evaluate it. Canadian case studies are presented to provide information on sedimentation rates and application of the various techniques. Future work that needs to be done is identified.

SUBJECT CROSS-REFERENCE INDEX

SUBJECT REFERENCE

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16. RESERVOIRS, LAKES AND DELTAS: 3,4,6,8,9,11,12,13,22,35,36,61,62,70,72,74,75, 78,79,80,91,102,104,105,106,107,109,115,117,118,119,125,128, 134,138,148,151,152,154,155,158,159,160,161,162,164,165,166, 167,168,175,176,179,190,191,199,204,205,206,208,209,210,212, 214,226,227,228,234,236,240,241,249,250,251,263,264,265,267, 268,269,277,278,285,286,287,290,292,304,305,307,308,309,311, 312,313,314.

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20. SUSPENDED SEDIMENT: 1,2,3,5,7,12,13,18,20,22,23,24,25,26,28,29,33,34,35,36,37, 38,39,40,41,42,43,44,45,46,47,48,49,50,55,57,59,62,63,64,65, 66,67,68,69,71,72,74,75,76,79,80,85,89,91,92,93,94,95,96,98, 105,106,107,111,112,114,115,116,117,119,121,122,125,126,128, 129,130,133,135,137,139,140,143,146,148,155,165,166,167,168, 169,170,171,172,173,174,175,176,177,178,180,181,182,183,184, 185,186,187,189,192,193,198,199,200,201,202,207,209,210,211, 212,214,215,217,219,220,221,222,223,224,225,226,227,228,229, 231,232,235,236,237,240,243,244,245,246,247,248,252,254,264, 265,266,267,268,271,274,275,276,280,281,282,283,287,289,291, 292,294,295,297,298,299,300,301,302,308,309,310,311,312,313, 314.

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